

tshingombe tshitadi

Prospect ID : 040320242059666073800f0884bebd2415f9d5d6b20c80a2237

Postdoctoral in 0

First Name : tshingombe

Last Name : tshitadi

Email : tshingombefiston@gmail.com

Alternative Email :

Address 1 :

Address 2 :

City : Johannesburg

State :

Country : South Africa

Home Phone :

Work Phone :

Cell Phone : 0725298946

Fax :

Age : 42

Gender :

Website Address :

Language : English

Internal Comments :

The AIU AI Program Generator creates custom program courses based on your desired work field and educational background. This intelligent tool tailors a curriculum to align with industry demands and your academic strengths, ensuring efficient learning and maximizing your potential for career success.

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<u>Course Name</u>	<u>Description</u>	<u>Date</u>	<u>Action</u>
Clean Energy Technology: Ecotechnology Applications	This course provides an in-depth understanding of ....	02/06/2025	
Integration of Electronic Engineering in Construction and Civil Engineering	This course aims to explore the integration of ele ....	02/06/2025	
Masters in Immutable Data Storage Solutions for Web Design	This course provides an advanced understanding of ....	02/06/2025	
Advanced Cyber-Physical Systems in Telecommunications	This course explores the intersection of cyber-phy ....	02/06/2025	
Master's Program in Artificial Intelligence and	This course provides an	02/06/2025	

Machine Learning for Software Engineering	in-depth exploration of ar ....		
Advanced Studies in Autonomous Vehicles and Drones for Electric Vehicle Engineering	This course provides an in-depth exploration of th ....	02/06/2025	
Specialist Engineering in Infrastructure and Contractors: Electrochemical Engineering	This Master's degree course offers in-depth knowle ....	02/06/2025	
Energy Storage and Battery Technology	This course explores advanced concepts in energy s ....	02/06/2025	
Advanced Robotic Process Automation in Electrical Engineering	This course aims to equip students with advanced k ....	02/06/2025	
Master's in Artificial General Intelligence and Social Sciences	This course aims to explore the intersection of Ar ....	01/28/2025	
Online Retail and E-commerce in the Renewable Energy Sector	This course explores the intersection of online re ....	01/28/2025	
Publishing and Natural Resources Management	This Masters-level course is designed to explore t ....	01/28/2025	
Masters in Supply Chain Management and Traceability	This course is designed for students pursuing a Ma ....	01/28/2025	
Social Media Marketing for Real Estate, Rental, and Leasing	This course is designed to equip students with the ....	01/28/2025	
Advanced Telemedicine and Remote Healthcare Production	This course is designed for Master's students focu ....	01/28/2025	
Technical Writing for Technology	This course is designed to prepare students with t ....	01/28/2025	
Masters in Vertical Farming and Urban Agriculture with Focus on Synthetic Biology	This course explores the intersection of vertical ....	01/28/2025	
Master's in Urban Water Supply, Sewerage, Waste Management, and Remediation Activities	This course delves into the complexities of urban ....	01/28/2025	
Transportation and Warehousing in Tourism Planning and Development	This course offers a comprehensive study into how ....	01/28/2025	
Spatial Computing in Telecommunications	This course explores the integration of spatial	01/28/2025	

	co ....		
<b>Advanced Pedagogical Training for Professionals in Scientific and Technical Services</b>	This Master's course is designed to equip individu ....	01/28/2025	
<b>Advanced Mechanical Engineering for Space Exploration and Aerospace</b>	This Master's level course provides an in-depth un ....	01/28/2025	
<b>Advanced Legal Studies in Public Administration and Safety</b>	This course is designed for Master's level student ....	01/28/2025	
<b>Metallurgy in Oil and Gas Production, Refining, and Transport</b>	This course provides an in-depth understanding of ....	01/28/2025	
<b>Integrated Water Management in Mining</b>	This course provides an in-depth analysis of integ ....	01/28/2025	
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<b>Data Processing and Hosting Services in Computer Engineering</b>	This course is designed for graduate students purs ....	01/28/2025	
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<b>Edge Computing in Modern Power and Energy Systems</b>	This course provides an in-depth exploration of ed ....	01/28/2025	
<b>Edge Computing for Modern Power and Energy Systems</b>	This advanced course explores the role and integra ....	01/28/2025	
<b>Masters in Cyber-Physical Systems and Information Technology</b>	This course provides an in-depth understanding of ....	01/28/2025	
<b>Masters in Distributed-Ledger Technology Applications in Educational Technology</b>	This course explores the integration of distribute ....	01/28/2025	
<b>Master's in Adult Education Services</b>	This course is designed for educators and professi ....	01/28/2025	
<b>Quantum Computing in Systems Engineering</b>	This course provides an in-depth exploration of qu ....	01/28/2025	

Neurotechnology in Educational Technology	This course explores the intersection of neurotech ....	01/28/2025	
Robotic Process Automation in Electrochemical Engineering	This course explores the integration of Robotic Pr ....	01/28/2025	
Integrating Educational Technology in Renewable Energy Studies	This course is designed for master's students inte ....	01/28/2025	
Wholesale Trade Management in Industrial Engineering	This course is designed for students pursuing a Ma ....	01/28/2025	
Advanced Wireless Communications	This course explores the fundamental principles an ....	01/28/2025	
Advanced Electrical Engineering in Construction and Civil Engineering	This course provides an in-depth understanding of ....	01/28/2025	
Electrical Systems in Construction and Civil Engineering	This master's level course is designed to bridge t ....	01/28/2025	
Doctorate in Specialist Engineering Infrastructure and Contractors: Electrical Engineering	This advanced course is designed for students purs ....	11/22/2024	

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- user\_id : 040320242059666073800f0884bebd2415f9d5d6b20c80a2237
- username:tshingombe
- email:tshitadi
- password: kananga5
- address

2. Products Table:

- product\_id : 040320242059666073800f0884bebd2415f9d5d6b20c80a2237
- name: engineering
- description: circulum assessment
- price: 1000\$
- category\_id:45677

3. Categories Table:

- category\_id : 040320242059666073800f0884bebd2415f9d5d6b20c80a2237
- name

4. Orders Table:

- order\_id : 040320242059666073800f0884bebd2415f9d5d6b20c80a2237
- user\_id :9879
- order\_date:25/02/2025
- total\_amount

5. Order\_Items Table:

- order\_item\_id : 040320242059666073800f0884bebd2415f9d5d6b20c80a2237
- order\_id : 123456
- product\_id:tshi
- quantity:100
- item\_price :10000\$



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## 1.Topic one experimental: theoretical practical company

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electrical service connection no greater than 56 kVA (3 phase, 80 ampere). In general most households would have this type of service connection. A Large Power User is defined as a user who has an electrical service connection larger than 56 kVA. In general these type of connections are used for medium and large commercial or industrial consumers as well as high density residential developments.

We want to provide property owners with the services they require in as short time as possible. To assist with this, the information and documents required to make an application for electrical services are detailed in the documents on this webpage.

1. Apply to convert a SPU from postpaid to pre-paid billing
2. Apply for a new prepaid or postpaid SPU connection ( this guide also covers application for alterations to a small power user connection)
3. Apply for a new LPU connection (the guide also covers applications for alterations to a large power user connection)

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application can also be found with the downloadable documents on the below table.

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AS8PR02MB8519.eurprd02.prod.outlook.com 2024,  
System@successfactors.com Remote server 12:55 PM

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electricity consumption.<sup>[30]</sup>

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<a href="#">Engineers in Training X09 Electrical HC x2 C and I x3 Mechanical or Chemical x3 Industrial Engineering x1 (Gx Kusile Powe</a>	2024/05/19 09:36 AM
<a href="#">Senior-Clerk-General-Administration-(Dx)-CPM-Aliwal-North</a>	2024/05/19 09:38 AM
<a href="#">Engineer Prof Engineering (NP)Distribution Bloemfontein</a>	2024/05/19 09:38 AM
<a href="#">Middle Manager Nuclear Safety and Assurance (ISED) X1 (Generation) Koeberg NPS</a>	2024/05/19 09:39 AM
<a href="#">Senior Advisor Education and Training (ETD) x1 (Engineering and Maintenance) Peaking</a>	2024/05/29 02:40 PM
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<a href="#">1 Learning-Programme-Engineer-in-Training-x-2,-Generation,-Megawatt-Park</a>	2024/09/01 01:29 PM
<a href="#">Learning Programme Engineer in Trainng x17 GX Matla Power Station</a>	2024/09/01 01:29 PM
<a href="#">Manager Site Outage Execution, Generation, Tutuka Power Station</a>	2024/09/01 01:30 PM
<a href="#">Re Advert Snr Technologist Electrical Engineering Substation x2 ( National Transmission Company South Africa) MWP Sunninghill</a>	2024/09/01 01:31 PM
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<a href="#">Senior Technician Chemistry x2 (Technical Support and Oils Micro) (Generation) Koeberg NPS</a>	2024/09/01 01:32 PM
<a href="#">Officer Safety Health Environment X1 Generation Medupi Power Station</a>	2024/09/01 01:33 PM
<a href="#">Learning Programme Outages x1 - Graduate in Training , Generation, Megawatt Park and Witbank</a>	2024/09/01 01:34 PM
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<a href="#">Power Stat</a>	
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<a href="#">Snr. Supervisor Tech Instrument x 2 (Generation) Tutuka Power Station</a>	2024/09/01 01:39 PM
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<a href="#">Learning Programme - Graduate in Training x1, Generation, Megawatt Park</a>	2024/09/01 01:44 PM
<a href="#">Learning-Programme -Graduate-in-Training-x3,-Generation,-1Megawatt-Park</a>	2024/09/01 01:45 PM
<a href="#">Learning Programme-Graduate in Training x 3, Generation, Megawatt Park</a>	2024/09/01 01:46 PM
<a href="#">Learning Programme-Graduate in Training x 2, Generation, Megawatt Park</a>	2024/09/01 01:47 PM
<a href="#">Senior Supervisor Technical Projects ( National Transmission Company South Africa )Northwest and Limpopo</a>	2024/09/01 01:49 PM
<a href="#">Snr-Advisor-Applications-Support-(Group-IT-DIVISION)-Megawatt-Park</a>	2024/09/01 01:50 PM

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On Sat, Nov 30, 2024 at 5:38 PM tshingombe fiston <[tshingombefiston@gmail.com](mailto:tshingombefiston@gmail.com)> wrote:

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The service connections we provide are divided into two categories namely Small Power Users (SPU) and Larger Power Users (LPU). A Small Power User is defined as a user who has an electrical service connection no greater than 56 kVA (3 phase, 80 ampere). In general most households would have this type of service connection. A Large Power User

is defined as a user who has an electrical service connection larger than 56 kVA. In general these type of connections are used for medium and large commercial or industrial consumers as well as high density residential developments.

We want to provide property owners with the services they require in as short time as possible. To assist with this, the information and documents required to make an application for electrical services are detailed in the documents on this webpage.

1. Apply to convert a SPU from postpaid to pre-paid billing
2. Apply for a new prepaid or postpaid SPU connection ( this guide also covers application for alterations to a small power user connection)
3. Apply for a new LPU connection (the guide also covers applications for alterations to a large power user connection)

The application form that needs to be submitted when making an

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City Power Johannesburg

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## City Power Johannesburg

Customer-focused energy services company, operating and maintaining the Johannesburg's electricity distribution network.

Electric Power Transmission, Control, and Distribution

Johannesburg, Gauteng

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[By Kgagodi MadibaCity Power is taking significant strides to reduce greenhouse gas emissions and bring sustainable energy solutions to Johannesburg co](#)

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[1 1 new message notification](#)

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[Messaging](#)

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[Notifications](#)

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application can also be found with the downloadable documents on the below table.

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<https://www.sars.gov.za/businesses-and-employers/trusts/registering-as-a-trust/register-a-trust-supporting-documents/>

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tshingombe On Mon, 02 Dec 2024, 10:26 RegionB Revenue, Feb 2,  
fiston <regionBrevenue@joburg.org.za> wrote: On Sat, Nov 30, 2024 at 2025,  
5:38 PM tshingombe fiston <tshingombefiston@gmail.com> 2:29 PM

tshingombe fiston <tshingombefiston@gmail.com> Feb 3, 2025, 11:36 AM

to regionArevenue, wmcqueries, Mediadesk, estimations, tenderadvicecentre, RegionB

6 Attachments • Scanned by Gmail

<b>RegionB Revenue</b>	Dear valued customer, Please provide us with your municipal account number and describe the nature of your query in detail. Thank you for utilizing the regional	<b>Feb 5, 2025, 12:50 PM</b>
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tshingombe Thanks - municipality city Johannesburg - CDs Feb 5, 2025,  
fiston R169241870 -; 1:19 PM

<b>RegionB Revenue</b>	Dear valued customer, Kindly provide a transfer letter The Region B Feb 5, Customer Service Team On Mon, Dec 2, 2024 at 10:26 AM RegionB 2025, Revenue <regionBrevenue@joburg> 1:35 PM
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tshingombe Thank you, will do. Feb 6, 2025, 9:33 AM  
fiston

<b>RegionB Revenue</b>	Thanks City Power Johannesburg Visit website Feed post Revenue number 1	<b>Feb 7, 2025, 8:58 AM</b>
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**RegionB Revenue** Feb 10, 2025, 8:06 AM

to me

Dear valued customer,

Thank you for utilizing the regional email service.

Kind Regards,

tshingombe You are welcome. Feb 10, 2025, 6:03 PM  
fiston

**RegionB Revenue** Feb 12, 2025, 10:43 AM (12 days ago)

to me

Most Welcome

tshingombe fiston <tshingombefiston@gmail.com> Feb 23, 2025, 10:28 AM (1 day ago)

to **RegionB**

2 Attachments • Scanned by Gmail

tshingombe fiston <tshingombefiston@gmail.com> Feb 23, 2025, 1:18 PM (21 hours ago)

to RegionB

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## City Power



- [Article](#)
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### Tools

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## Appearance

### Text

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Small



Standard



Large

### Width

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☐ Standard

☐ Wide

Color (beta)



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☐ Automatic

☐ Light

☐ Dark

From Wikipedia, the free encyclopedia

City Power	
<div><div></div><div></div></div>	
Company type	<a href="#">Electric utility</a>
Industry	<a href="#">Electric power industry</a>
Founded	January 1, 2001; 24 years ago
Headquarters	40 Heronmere Road, <a href="#">Reuven</a> , <a href="#">Johannesburg</a> , , <a href="#">South Africa</a>
Area served	Johannesburg
Key people	<div><ul style="list-style-type: none"><li>Tshifularo Mashava (<a href="#">CEO</a>)</li></ul></div>
Revenue	<span>▲</span> <a href="#">R</a> 17 billion (2020/21)
<a href="#">Total assets</a>	<span>▲</span> <a href="#">R</a> 19.7 billion (2019/20)
Number of employees	1750 (2020/21)
Website	<a href="http://citypower.co.za">citypower.co.za</a>

City Power Johannesburg (or Joburg City Power) is a [state owned power utility](#), wholly owned by the [City of Johannesburg](#). Its responsibilities include buying electricity from power producers and supplying it to the public, and installing and maintaining the electrical infrastructure in the city of Johannesburg. It supplies electricity to 3.2 million people in the Greater Johannesburg Metropolitan Area.<sup>[[1](#)]</sup>

## History

Joburg City Power was established as a separate company from the City of Johannesburg on 1 January 2000. On the 19th December 2001, the [National Energy Regulator of South Africa](#) (NERSA), granted City Power a licence to trade.

In 2022, it took over the electricity distribution functions from [Eskom](#) to [Soweto](#) and parts of Johannesburg, including [Sandton](#), [Orange Farm](#), Finetown, [Ivory Park](#) and [Diepsloot](#); Eskom was previously responsible for supplying electricity to most parts of Johannesburg.<sup>[2][3]</sup>

## Corruption

In 2013, a controversial [R1.2 billion](#) contract was awarded by the City of Johannesburg to Edison Power, a company owned by [Vivian Reddy](#), a close ally of [Jacob Zuma](#), for smart meters used by City Power customers.<sup>[4]</sup> Edison Power was initially allocated a R600-million share of an R800-million contract. Subsequently, the contract value was revised to R1.25 billion and Edison Power received the exclusive contract.<sup>[4]</sup>

## Load shedding



Kelvin Power Station, a [coal-fired power station](#), provides the City of Johannesburg 10% of its power.

City Power currently obtains 90% of its power from Eskom and 10% from the [Kelvin Power Station](#) from which it seeks to move away from.<sup>[5]</sup>

In 2014, it announced that it will remotely switch off [geysers](#) "to reduce the impact of load shedding."<sup>[6]</sup>

In 2021, it resolved to be an electricity generator to "reduce over-reliance on Eskom".<sup>[7]</sup> In 2023, the City of Johannesburg along with City Power aimed to cut [load shedding](#) in Johannesburg by 3 stages through the use of [smart meters](#) and the recommissioning of two existing [open cycle gas turbines](#). It also sought to secure power on a long-term basis from [independent power producers](#) (IPPs).<sup>[8]</sup>

In 2023, City Power said it had to replace more than 390 mini-substations (pole-mounted [transformers](#)), at a cost of R200 million which constituted 80% of its budget for the year. The cause of this was load shedding, theft and vandalism.<sup>[9][10][11]</sup>

In September 2023, City Power announced a drive that would replace all meters with [smart meters](#) before 24 November 2024. This was due to a limitation in all meters that generate a token ID using the [Standard Transfer Specification](#). This change would also enable City Power to remotely limit electricity usage in households whose usage is higher than normal.<sup>[12]</sup>

From 6 November 2023, City Power took over management of the load shedding schedule from Eskom.<sup>[13]</sup>

From 10 June 2024, City Power implemented its own form of load shedding called load reduction.<sup>[14]</sup>

#### Electricity procurement

In 2023, through [grid access](#) it aims to obtain 53MW from customer-embedded [rooftop solar](#) generation and 3.7MW from municipal building [PV](#) generation, for a total of 60MW.<sup>[2]</sup>

By 2026/27, it hopes to target 480MW (with 200MW coming from households and businesses, 150MW from [independent power producers](#) on private and mining land, 50MW from financed rooftop IPP PV programmes, 27MW through municipal building PV generation, 33.5MW from [landfill gas generation](#) and solid [waste-to-energy](#), and 20MW from [natural gas](#) generation.)<sup>[2]</sup>

In July 2023, the City of Johannesburg introduced wheeling tariffs which charge both independent power producers and City Power customers to allow use of the existing grid infrastructure to supply customers with electricity.<sup>[15]</sup>

In August 2023, City Power secured 92MW from four IPPs: [waste-to-energy](#) (20MW), gas-to-power (31MW) and PV solar generation (40.8MW).<sup>[16]</sup>

In April 2024, the 50 MW John Ware Gas Turbine Power Station was recommissioned.<sup>[17]</sup>

#### Revenue recuperation

City Power has endeavoured to collect R8.9 billion owed by businesses and households. It did this by first giving notices of disconnecting the power of delinquent parties, and compelling them to pay. It said it will impose penalties on businesses and residential complexes that have defaulted on their accounts and connected electricity illegally.<sup>[18]</sup>

#### Businesses

The [Apartheid Museum](#) was one of the disconnected clients, with it owing R1.8 million.<sup>[19]</sup> The Gauteng Treasury was another, with it owing over R34 million.<sup>[20]</sup> In February 2023, some of the disconnected clients were a shopping centre running an illegal connection on

its meters and was penalised with a R100 000 fine, the [Church of Scientology](#) with R877 000 in arrears, a sports club in [Bryanston](#) which owed R2.3 million and the Nigerian consulate which owed R406 000.<sup>[18]</sup>

In October 2023, it announced that it would give government entities [Rahima Moosa Mother and Child Hospital](#) and the [Helen Joseph Hospital](#) 14 days to settle a combined debt of R32 million.<sup>[21]</sup>

In June 2024, Eskom issued an ultimatum to the City of Johannesburg (COJ) and City Power for electricity non payment. Joburg owes Eskom R3.4 billion.<sup>[22]</sup> According to the record, last payments were made in October 2023.<sup>[23]</sup> The Johannesburg High Court instructed the City of Johannesburg and City Power to immediately pay the first billion of their defaulting amount.<sup>[24]</sup>

Residential customers

In September 2023, City Power conducted a disconnection drive of non-paying customers in Naturena and the [Lenasia](#) Service Delivery Centre (SDC) in an attempt to collect revenue; the Lenasia SDC which includes surrounding areas like [Eldorado Park](#), [Ennerdale](#), Zakariyya Park and Lehae, owed R 1.3 billion.<sup>[25]</sup>

The City of Johannesburg, through City Power meters, began subtracting municipal debt owed by businesses and residential customers from prepaid electricity purchases.<sup>[26]</sup>

From July 2024, City Power began deducting a R230 service charge from its prepaid customers; along with an increase in the electricity price per KWh, this saw a 23.15% increase from the previous year for all customers including indigent customers (6 to 12 times the inflation rate).<sup>[27][28]</sup>

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- [Customer expectations](#)

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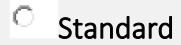
- ## References

Electric utility



- Appearance  
Text

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- Small



☐ Large

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☐ Standard

☐ Wide

Color (beta)

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From Wikipedia, the free encyclopedia

An electric utility, or a power company, is a company in the [electric power industry](#) (often a [public utility](#)) that engages in [electricity generation](#) and [distribution of electricity](#) for sale generally in a [regulated market](#).<sup>[1]</sup> The electrical utility industry is a major provider of energy in most countries.

Electric utilities include [investor owned](#), [publicly owned](#), [cooperatives](#), and [nationalized](#) entities. They may be engaged in all or only some aspects of the industry. [Electricity markets](#) are also considered electric utilities—these entities buy and sell electricity, acting as brokers, but usually do not own or operate generation, transmission, or distribution facilities. Utilities are regulated by local and national authorities.

Electric utilities are facing increasing demands<sup>[2]</sup> including [aging infrastructure](#), reliability, and regulation.

In 2009, the French company EDF was the world's largest producer of electricity.<sup>[3]</sup>

Organization

Power transactions

An [electric](#) power system is a group of generation, transmission, distribution,

communication, and other facilities that are physically connected.<sup>[4]</sup> The flow of electricity within the system is maintained and controlled by dispatch centers which can buy and sell electricity based on system requirements.

## Executive compensation



The examples and perspective in this article may not represent a [worldwide view](#) of the subject. You may [improve this article](#), discuss the issue on the [talk page](#), or [create a new article](#), as appropriate. (February 2016) ([Learn how and when to remove this message](#))

The [executive compensation](#) received by the executives in utility companies often receives the most scrutiny in the review of [operating expenses](#). Just as regulated utilities and their governing bodies struggle to maintain a balance between keeping consumer costs reasonable and being profitable enough to attract investors, they must also compete with private companies for talented executives and then be able to retain those executives.<sup>[5]</sup>

Regulated companies are less likely to use incentive-based [remuneration](#) in addition to base salaries. Executives in regulated electric utilities are less likely to be paid for their performance in bonuses or [stock options](#).<sup>[5]</sup> They are less likely to approve compensation policies that include incentive-based pay.<sup>[5]</sup> The compensation for electric utility executives will be the lowest in regulated utilities that have an unfavorable regulatory environment. These companies have more political constraints than those in a favorable regulatory environment and are less likely to have a positive response to requests for rate increases.<sup>[6]</sup>

Just as increased constraints from regulation drive compensation down for executives in electric utilities, [deregulation](#) has been shown to increase remuneration. The need to encourage risk-taking behavior in seeking new investment opportunities while keeping costs under control requires deregulated companies to offer performance-based incentives to their executives. It has been found that increased compensation is also more likely to attract executives experienced in working in competitive environments.<sup>[7]</sup>

In the United States, the [Energy Policy Act of 1992](#) removed previous barriers to wholesale competition in the electric utility industry. Currently 24 states allow for deregulated electric utilities: Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, Texas, Virginia, Arizona, Arkansas, California, Connecticut, Delaware, Illinois, Maine, Maryland, Massachusetts, Michigan, Montana, New Hampshire, New Jersey, New Mexico, New York, and Washington D.C.<sup>[8]</sup> As electric utility monopolies have been increasingly broken up into deregulated businesses, executive compensation has risen; particularly incentive compensation.<sup>[9]</sup>

## Oversight

Oversight is typically carried out at the national level, however it varies depending on financial support and external influences.<sup>[10]</sup> There is no existence of any influential

international energy oversight organization. There does exist a World Energy Council, but its mission is mostly to advise and share new information.<sup>[11]</sup> It does not hold any kind of legislative or executive power.

#### Alternative energy promotion

[Alternative energy](#) has become more and more prevalent in recent times and as it is inherently independent of more traditional sources of energy, the market seems to have a very different structure. In the United States, to promote the production and development of alternative energies, there are many subsidies, rewards, and incentives that encourage companies to take up the challenge themselves. There is precedent for such a system working in countries like Nicaragua. In 2005, Nicaragua gave renewable energy companies tax and duty exemptions, which spurred a great deal of private investment.<sup>[12]</sup>

The success in Nicaragua may not be an easily replicated situation however. The movement was known as Energiewende and it is generally considered a failure for many reasons.<sup>[13]</sup> A primary reason was that it was improperly timed and was proposed during a period in which their energy economy was under more competition.

Globally, the transition of electric utilities to renewables remains slow, hindered by concurrent continued investment in the expansion of fossil fuel capacity.<sup>[14]</sup>

#### Nuclear energy

Nuclear energy may be classified as a green source depending on the country. Although there used to be much more privatization in this energy sector, after the 2011 Fukushima district nuclear power plant disaster in Japan, there has been a move away from nuclear energy itself, especially for privately owned nuclear power plants.<sup>[citation needed]</sup> The criticism being that privatization of companies tend to have the companies themselves cutting corners and costs for profits which has proven to be disastrous in the worst-case scenarios. This placed a strain on many other countries as many foreign governments felt pressured to close nuclear power plants in response to public concerns.<sup>[13]</sup> Nuclear energy however still holds a major part in many communities around the world.

#### Customer expectations

Utilities have found that it isn't simple to meet the unique needs of individual customers, whether residential, corporate, industrial, government, military, or otherwise. Customers in the twenty-first century have new and urgent expectations that demand a transformation of the electric grid. They want a system that gives them new tools, better data to help manage energy usage, advanced protections against cyberattacks, and a system that minimizes outage times and quickens power restoration.<sup>[15]</sup>

See also

Electrical grid



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## Tools

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## Appearance

Text

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 Small☐ Standard

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Color (beta)

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☐ Light

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From Wikipedia, the free encyclopedia

(Redirected from [Grid access](#))

For other uses, see [Grid \(disambiguation\)](#).

"Power grid" redirects here. For the board game, see [Power Grid](#).

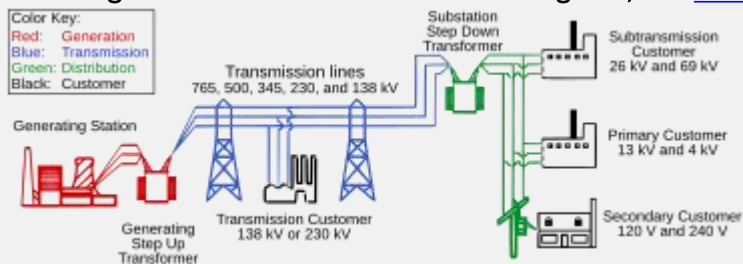


Diagram of an electrical grid

(generation system in red, transmission system in blue, distribution system in green)

An electrical grid (or electricity network) is an interconnected network for [electricity delivery](#) from producers to consumers. Electrical grids consist of [power stations](#), [electrical substations](#) to step [voltage](#) up or down, [electric power transmission](#) to carry power over long distances, and finally [electric power distribution](#) to customers. In that last step, voltage is stepped down again to the required service voltage. Power stations are typically built close to energy sources and far from densely populated areas. Electrical grids vary in size and can cover whole countries or continents. From small to large there are [microgrids](#), [wide area synchronous grids](#), and [super grids](#). The combined transmission and distribution network is part of electricity delivery, known as the *power grid*.

Grids are nearly always synchronous, meaning all distribution areas operate with [three phase alternating current](#) (AC) frequencies synchronized (so that voltage swings occur at

almost the same time). This allows transmission of AC power throughout the area, connecting the electricity generators with consumers. Grids can enable more efficient [electricity markets](#).

Although electrical grids are widespread, as of 2016, 1.4 billion people worldwide were not connected to an electricity grid.<sup>[1]</sup> As [electrification](#) increases, the number of people with access to grid electricity is growing. About 840 million people (mostly in Africa), which is ca. 11% of the World's population, had no access to grid electricity in 2017, down from 1.2 billion in 2010.<sup>[2]</sup>

Electrical grids can be prone to malicious intrusion or attack; thus, there is a need for [electric grid security](#). Also as electric grids modernize and introduce computer technology, cyber threats start to become a security risk.<sup>[3]</sup> Particular concerns relate to the more complex computer systems needed to manage grids.<sup>[4]</sup>

Types (grouped by size)

Part of <a href="#">a series</a> on
<a href="#">Power engineering</a>
<a href="#">Electric power conversion</a>
<ul style="list-style-type: none"> <li>• <a href="#">Voltage converter</a></li> <li>• <a href="#">Electric power conversion</a></li> <li>• <a href="#">HVDC converter station</a></li> <li>• <a href="#">AC-to-AC converter</a></li> <li>• <a href="#">DC-to-DC converter</a></li> <li>• <a href="#">Rectifier</a></li> <li>• <a href="#">Inverter</a></li> </ul>
<a href="#">Electric power infrastructure</a>
<ul style="list-style-type: none"> <li>• <a href="#">Electric power system</a></li> <li>• <a href="#">Power station</a></li> <li>• <a href="#">Electrical grid</a></li> <li>• <a href="#">Interconnector</a></li> <li>• <a href="#">Demand response</a></li> </ul>
<a href="#">Electric power systems components</a>
<ul style="list-style-type: none"> <li>• <a href="#">Ring main unit</a></li> <li>• <a href="#">Grid-tie inverter</a></li> <li>• <a href="#">Energy storage</a></li> <li>• <a href="#">Busbar</a></li> <li>• <a href="#">Bus duct</a></li> <li>• <a href="#">Recloser</a></li> <li>• <a href="#">Protective relay</a></li> </ul>

- [v](#)
- [t](#)
- [e](#)

## Microgrid

Main article: [Microgrid](#)

A microgrid is a local grid that is usually part of the regional wide-area synchronous grid, but which can disconnect and operate autonomously.<sup>[5]</sup> It might do this in times when the main grid is affected by outages. This is known as [islanding](#), and it might run indefinitely on its own resources.

Compared to larger grids, microgrids typically use a lower voltage distribution network and distributed generators.<sup>[6]</sup> Microgrids may not only be more resilient, but may be cheaper to implement in isolated areas.

A design goal is that a local area produces all of the energy it uses.<sup>[5]</sup>

Example implementations include:

- [Hajjah](#) and [Lahj](#), Yemen: community-owned solar microgrids.<sup>[7]</sup>
- [Île d'Yeu](#) pilot program: sixty-four solar panels with a peak capacity of 23.7 kW on five houses and a battery with a storage capacity of 15 kWh.<sup>[8][9]</sup>
- [Les Anglais](#), Haiti:<sup>[10]</sup> includes energy theft detection.<sup>[11]</sup>
- [Mpeketoni](#), Kenya: a community-based diesel-powered micro-grid system.<sup>[12]</sup>
- Stone Edge Farm Winery: micro-turbine, fuel-cell, multiple battery, hydrogen electrolyzer, and PV enabled winery in [Sonoma, California](#).<sup>[13][14]</sup>

## Wide area synchronous grid

Main article: [Wide area synchronous grid](#)

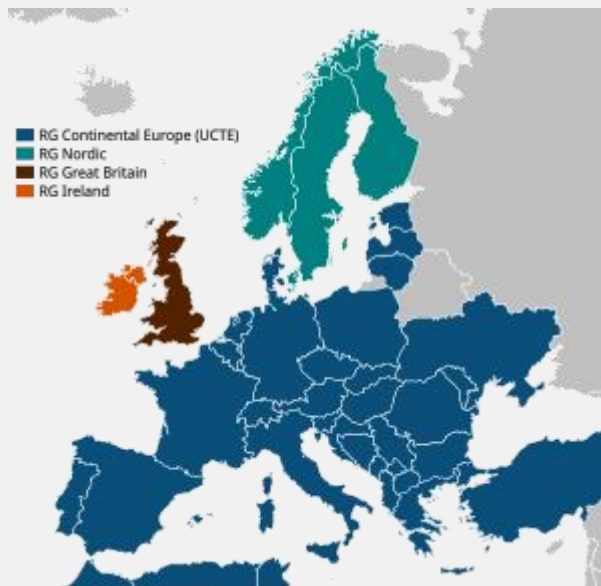
A *wide area synchronous grid* (also called an "interconnection" in North America) is an electrical grid at a regional scale or greater that operates at a synchronized frequency and is electrically tied together during normal system conditions. For example, there are four major interconnections in North America (the [Western Interconnection](#), the [Eastern Interconnection](#), the [Quebec Interconnection](#) and the [Texas Interconnection](#)). In Europe, [one large grid connects most of Western Europe](#). These are also known as synchronous zones, the largest of which is the [synchronous grid of Continental Europe](#) (ENTSO-E) with 667 [gigawatts](#) (GW) of generation, and the widest region served being that of the [IPS/UPS](#) system serving countries of the former Soviet Union. Synchronous grids with ample capacity facilitate [electricity market](#) trading across wide areas. In the ENTSO-E in 2008, over

350,000 megawatt hours were sold per day on the [European Energy Exchange](#) (EEX).<sup>[15]</sup>

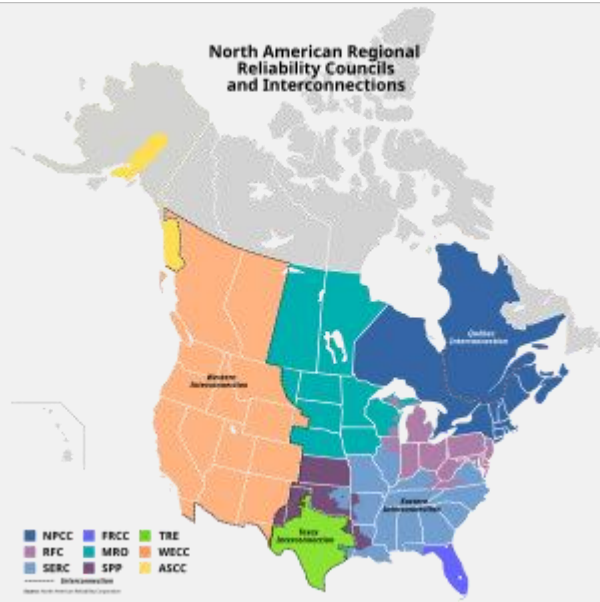
Each of the interconnectors in North America are run at a nominal 60 Hz, while those of Europe run at 50 Hz. Neighbouring interconnections with the same frequency and standards can be synchronized and directly connected to form a larger interconnection, or they may share power without synchronization via high-voltage direct current [power transmission lines](#) (DC ties), or with variable-frequency transformers (VFTs), which permit a controlled flow of energy while also functionally isolating the independent AC frequencies of each side.

The benefits of synchronous zones include pooling of generation, resulting in lower generation costs; pooling of load, resulting in significant equalizing effects; common provisioning of reserves, resulting in cheaper primary and secondary reserve power costs; opening of the market, resulting in possibility of long-term contracts and short term power exchanges; and mutual assistance in the event of disturbances.<sup>[16]</sup>

One disadvantage of a wide-area synchronous grid is that problems in one part can have repercussions across the whole grid. For example, in 2018, [Kosovo](#) used more power than it generated due to a dispute with [Serbia](#), leading to the phase across the whole [synchronous grid of Continental Europe](#) lagging behind what it should have been. The frequency dropped to 49.996 Hz. This caused certain kinds of [clocks](#) to become six minutes slow.<sup>[17]</sup>



The synchronous grids of Europe



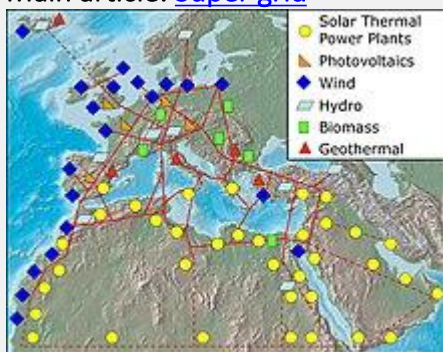
The two major and three minor interconnections of North America



Major WASGs around the world

Super grid

Main article: [Super grid](#)



One conceptual plan of a super grid linking renewable sources across North Africa, the Middle East and Europe. ([DESERTEC](#))<sup>[18]</sup>

A *super grid* or *supergrid* is a wide-area transmission network that is intended to make

possible the trade of high volumes of electricity across great distances. It is sometimes also referred to as a *mega grid*. Super grids can support a global [energy transition](#) by smoothing local fluctuations of [wind energy](#) and [solar energy](#). In this context, they are considered as a key technology to [mitigate global warming](#). Super grids typically use [high-voltage direct current](#) (HVDC) to transmit electricity long distances. The latest generation of HVDC power lines can transmit energy with losses of only 1.6% per 1000 km.<sup>[19]</sup>

Electric utilities between regions are many times interconnected for improved economy and reliability. [Electrical interconnectors](#) allow for economies of scale, allowing energy to be purchased from large, efficient sources. Utilities can draw power from generator reserves from a different region to ensure continuing, reliable power and diversify their loads. Interconnection also allows regions to have access to cheap bulk energy by receiving power from different sources. For example, one region may be producing cheap hydro power during high water seasons, but in low water seasons, another area may be producing cheaper power through wind, allowing both regions to access cheaper energy sources from one another during different times of the year. Neighboring utilities also help others to maintain the overall system frequency and also help manage tie transfers between utility regions.<sup>[20]</sup>

Electricity Interconnection Level (EIL) of a grid is the ratio of the total interconnector power to the grid divided by the installed production capacity of the grid. Within the EU, it has set a target of national grids reaching 10% by 2020, and 15% by 2030.<sup>[21]</sup>

## Components

### Generation

Main article: [Electricity generation](#)



[Turbo generator](#)

Electricity generation is the process of generating [electric power](#) at [power stations](#). This is done ultimately from sources of [primary energy](#) typically with [electromechanical generators](#) driven by [heat engines](#) from [fossil](#), [nuclear](#), and [geothermal](#) sources, or driven by the [kinetic energy](#) of water or wind. Other power sources are [photovoltaics](#) driven by solar insolation,

and [grid batteries](#).<sup>[nb 1]</sup>

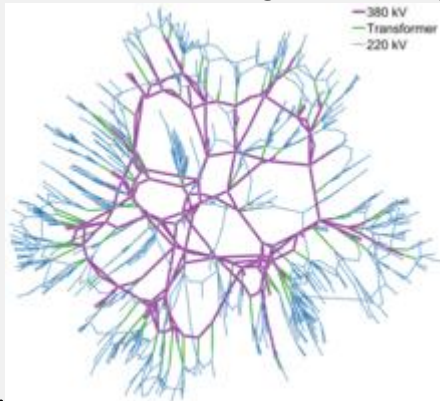
The sum of the power outputs of generators on the grid is the production of the grid, typically measured in [gigawatts](#) (GW).

Transmission

Main article: [Electric power transmission](#)



500 kV [Three-phase electric power](#) Transmission Lines at [Grand Coulee Dam](#); four circuits are shown; two additional circuits are obscured by trees on the right; the entire 7079 MW generation capacity of the dam is accommodated by these



six circuits.

Network diagram of a high voltage transmission system, showing the interconnection between the different voltage levels. This diagram depicts the electrical structure<sup>[22]</sup> of the network, rather than its physical geography.

Electric power transmission is the bulk movement of [electrical energy](#) from a generating site, via a web of interconnected lines, to an [electrical substation](#), from which is connected to the distribution system. This networked system of connections is distinct from the local wiring between high-voltage substations and customers. Transmission networks are complex with redundant pathways. Redundancy allows line failures to occur and power is simply rerouted while repairs are done.

Because the power is often generated far from where it is consumed, the transmission system can cover great distances. For a given amount of power, transmission efficiency is greater at higher voltages and lower currents. Therefore, voltages are stepped up at the generating station, and stepped down at local substations for distribution to customers.

Most transmission is [three-phase](#). Three-phase, compared to single-phase, can deliver much

more power for a given amount of wire, since the neutral and ground wires are shared.<sup>[23]</sup> Further, three-phase generators and motors are more efficient than their single-phase counterparts.

However, for conventional conductors one of the main losses are resistive losses which are a square law on current, and depend on distance. High voltage AC transmission lines can lose 1-4% per hundred miles.<sup>[24]</sup> However, [high-voltage direct current](#) can have half the losses of AC. Over very long distances, these efficiencies can offset the additional cost of the required AC/DC converter stations at each end.

## Substations

Main article: [Electrical substation](#)

Substations may perform many different functions but usually transform voltage from low to high (step up) and from high to low (step down). Between the generator and the final consumer, the voltage may be transformed several times.<sup>[25]</sup>

The three main types of substations, by function, are:<sup>[26]</sup>

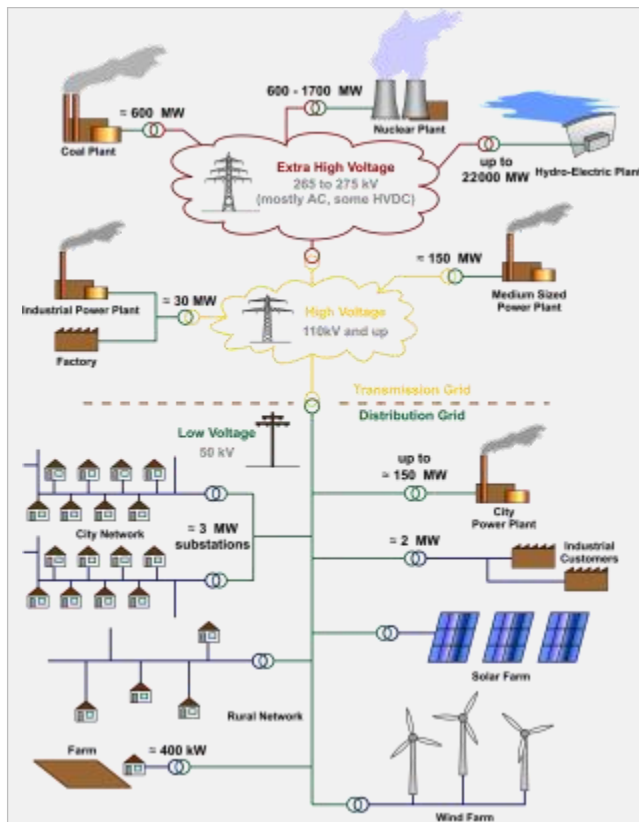
- Step-up substation: these use [transformers](#) to raise the voltage coming from the generators and power plants so that power can be transmitted long distances more efficiently, with smaller currents.
- Step-down substation: these transformers lower the voltage coming from the transmission lines which can be used in industry or sent to a distribution substation.
- Distribution substation: these transform the voltage lower again for the distribution to end users.

Aside from transformers, other major components or functions of substations include:

- [Circuit breakers](#): used to automatically break a circuit and isolate a fault in the system.<sup>[27]</sup>
- [Switches](#): to control the flow of electricity, and isolate equipment.<sup>[28]</sup>
- The substation [busbar](#): typically a set of three conductors, one for each phase of current. The substation is organized around the buses, and they are connected to incoming lines, transformers, protection equipment, switches, and the outgoing lines.<sup>[27]</sup>
- [Lightning arresters](#)
- [Capacitors](#) for [power factor](#) correction
- [Synchronous condensers](#) for power factor correction and grid stability

## Electric power distribution

Main article: [Electric power distribution](#)



General layout of electricity grids. Voltages and depictions of electrical lines are typical for Germany and other European systems.

Distribution is the final stage in the delivery of power; it carries electricity from the transmission system to individual consumers. Substations connect to the transmission system and lower the transmission voltage to medium voltage ranging between 2 [kV](#) and 35 kV. But the voltage levels varies very much between different countries, in Sweden medium voltage are normally 10 [kV](#) between 20 kV.<sup>[29]</sup> Primary distribution lines carry this medium voltage power to [distribution transformers](#) located near the customer's premises. Distribution transformers again lower the voltage to the [utilization voltage](#). Customers demanding a much larger amount of power may be connected directly to the primary distribution level or the [subtransmission](#) level.<sup>[30]</sup>

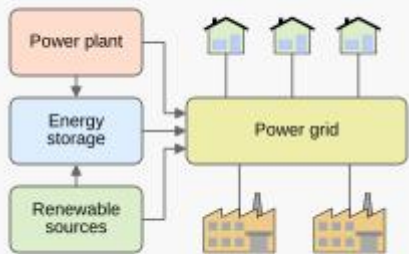
Distribution networks are divided into two types, radial or network.<sup>[31]</sup>

In cities and towns of North America, the grid tends to follow the classic *radially fed* design. A substation receives its power from the transmission network, the power is stepped down with a transformer and sent to a [bus](#) from which feeders fan out in all directions across the countryside. These feeders carry three-phase power, and tend to follow the major streets near the substation. As the distance from the substation grows, the fanout continues as smaller laterals spread out to cover areas missed by the feeders. This tree-like structure grows outward from the substation, but for reliability reasons, usually contains at least one unused backup connection to a nearby substation. This connection can be enabled in case of an emergency, so that a portion of a substation's service territory can be alternatively fed

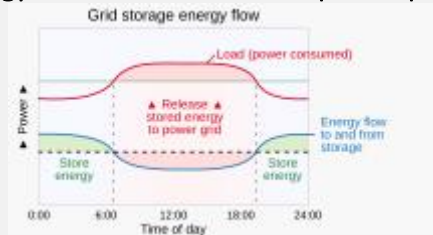
by another substation.

Storage

Main article: [Grid energy storage](#)



Energy from fossil or nuclear power plants and renewable



sources is stored for use by customers.  
energy flow over the course of a day

Simplified grid

*Grid energy storage* (also called *large-scale energy storage*) is a collection of methods used for [energy storage](#) on a large scale within an [electrical power grid](#). Electrical energy is stored during times when electricity is plentiful and inexpensive (especially from [intermittent power](#) sources such as [renewable electricity](#) from [wind power](#), [tidal power](#) and [solar power](#)) or when demand is low, and later power is generated when demand is high, and electricity prices tend to be higher.

As of 2020, the largest form of grid energy storage is dammed [hydroelectricity](#), with both conventional hydroelectric generation as well as [pumped storage hydroelectricity](#).

Developments in battery storage have enabled commercially viable projects to store energy during peak production and release during peak demand, and for use when production unexpectedly falls giving time for slower responding resources to be brought online.

Two alternatives to grid storage are the use of [peaking power plants](#) to fill in supply gaps and [demand response](#) to shift load to other times.

Functionalities

Demand

The demand, or load on an electrical grid is the total electrical power being removed by the

users of the grid.

The graph of the demand over time is called the *demand curve*.

[Baseload](#) is the minimum load on the grid over any given period, [peak demand](#) is the maximum load. Historically, baseload was commonly met by equipment that was relatively cheap to run, that ran continuously for weeks or months at a time, but globally this is becoming less common. The extra peak demand requirements are sometimes produced by expensive [peaking plants](#) that are generators optimised to come on-line quickly but these too are becoming less common.

However, if the demand of electricity exceed the capacity of a local power grid, it will cause safety issue like burning out.<sup>[32]</sup>

## Voltage

Grids are designed to supply electricity to their customers at largely constant voltages. This has to be achieved with varying demand, variable [reactive](#) loads, and even nonlinear loads, with electricity provided by generators and distribution and transmission equipment that are not perfectly reliable.<sup>[33]</sup> Often grids use [tap changers](#) on transformers near to the consumers to adjust the voltage and keep it within specification.

## Frequency

Main article: [Utility frequency](#)

In a synchronous grid all the generators must run at the same frequency, and must stay very nearly in phase with each other and the grid. Generation and consumption must be balanced across the entire grid, because energy is consumed as it is produced. For rotating generators, a local [governor](#) regulates the driving torque, maintaining almost constant rotation speed as loading changes. Energy is stored in the immediate short term by the rotational kinetic energy of the generators.

Although the speed is kept largely constant, small deviations from the nominal system frequency are very important in regulating individual generators and are used as a way of assessing the equilibrium of the grid as a whole. When the grid is lightly loaded the grid frequency runs above the nominal frequency, and this is taken as an indication by [Automatic Generation Control](#) systems across the network that generators should reduce their output. Conversely, when the grid is heavily loaded, the frequency naturally slows, and governors adjust their generators so that more power is output ([droop speed control](#)). When generators have identical droop speed control settings it ensures that multiple parallel generators with the same settings share load in proportion to their rating.

In addition, there's often central control, which can change the parameters of the AGC

systems over timescales of a minute or longer to further adjust the regional network flows and the operating frequency of the grid.

For timekeeping purposes, the nominal frequency will be allowed to vary in the short term, but is adjusted to prevent line-operated clocks from gaining or losing significant time over the course of a whole 24 hour period.

An entire synchronous grid runs at the same frequency, neighbouring grids would not be synchronised even if they run at the same nominal frequency. [High-voltage direct current](#) lines or [variable-frequency transformers](#) can be used to connect two alternating current interconnection networks which are not synchronized with each other. This provides the benefit of interconnection without the need to synchronize an even wider area. For example, compare the wide area synchronous grid map of Europe with the map of HVDC lines.

#### Capacity and firm capacity

The sum of the maximum power outputs ([nameplate capacity](#)) of the generators attached to an electrical grid might be considered to be the capacity of the grid.

However, in practice, they are never run flat out simultaneously. Typically, some generators are kept running at lower output powers ([spinning reserve](#)) to deal with failures as well as variation in demand. In addition generators can be off-line for maintenance or other reasons, such as availability of energy inputs (fuel, water, wind, sun etc.) or pollution constraints.

Firm capacity is the maximum power output on a grid that is immediately available over a given time period, and is a far more useful figure.

#### Production

Most grid codes specify that the load is shared between the generators in [merit order](#) according to their [marginal cost](#) (i.e. cheapest first) and sometimes their environmental impact. Thus cheap electricity providers tend to be run flat out almost all the time, and the more expensive producers are only run when necessary.

#### Failures and issues

Failures are usually associated with generators or power transmission lines tripping circuit breakers due to faults leading to a loss of generation capacity for customers, or excess demand. This will often cause the frequency to reduce, and the remaining generators will react and together attempt to stabilize above the minimum. If that is not possible then a number of scenarios can occur.

A large failure in one part of the grid — unless quickly compensated for — can cause current to re-route itself to flow from the remaining generators to consumers over transmission lines of insufficient capacity, causing further failures. One downside to a widely connected grid is thus the possibility of [cascading failure](#) and widespread [power outage](#). A central authority is usually designated to facilitate communication and develop protocols to maintain a stable grid. For example, the [North American Electric Reliability Corporation](#) gained binding powers in the United States in 2006, and has advisory powers in the applicable parts of Canada and Mexico. The U.S. government has also designated [National Interest Electric Transmission Corridors](#), where it believes transmission bottlenecks have developed.

Brownout

Main article: [Brownout \(electricity\)](#)



A brownout near [Tokyo Tower](#) in [Tokyo, Japan](#)

A *brownout* is an intentional or unintentional drop in voltage in an electrical [power supply](#) system. Intentional brownouts are used for load reduction in an emergency.<sup>[34]</sup> The reduction lasts for minutes or hours, as opposed to short-term [voltage sag](#) (or dip). The term brownout comes from the dimming experienced by incandescent lighting when the voltage sags. A [voltage reduction](#) may be an effect of disruption of an electrical grid, or may occasionally be imposed in an effort to reduce load and prevent a [power outage](#), known as a [blackout](#).<sup>[35]</sup>

Blackout

Main article: [Power outage](#)

A *power outage* (also called a *power cut*, a *power out*, a *power blackout*, *power failure* or a *blackout*) is a loss of the electric power to a particular area.

Power failures can be caused by faults at power stations, damage to electric transmission

lines, [substations](#) or other parts of the [distribution](#) system, a [short circuit](#), [cascading failure](#), [fuse](#) or [circuit breaker](#) operation, and human error.

Power failures are particularly critical at sites where the environment and public safety are at risk. Institutions such as [hospitals](#), [sewage treatment](#) plants, [mines](#), shelters and the like will usually have backup power sources such as [standby generators](#), which will automatically start up when electrical power is lost. Other critical systems, such as [telecommunication](#), are also required to have emergency power. The [battery room](#) of a telephone exchange usually has arrays of [lead–acid batteries](#) for backup and also a socket for connecting a generator during extended periods of outage.

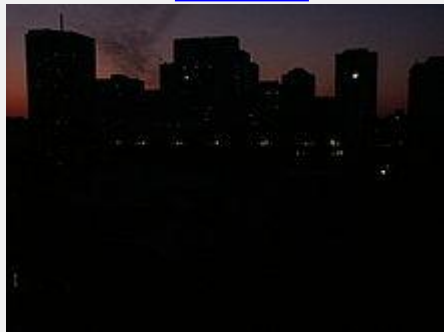
Load shedding

Main article: [Demand response](#)

[Electrical generation](#) and transmission systems may not always meet peak demand requirements— the greatest amount of [electricity](#) required by all utility customers within a given region. In these situations, overall demand must be lowered, either by turning off service to some devices or cutting back the supply voltage ([brownouts](#)), in order to prevent uncontrolled service disruptions such as power outages (widespread blackouts) or equipment damage. Utilities may impose load shedding on service areas via targeted blackouts, [rolling blackouts](#) or by agreements with specific high-use industrial consumers to turn off equipment at times of system-wide peak demand.

Black start

Main article: [Black start](#)



Toronto during the [Northeast blackout of 2003](#), which required black-starting of generating stations.

A *black start* is the process of restoring an electric power station or a part of an [electric grid](#) to operation without relying on the external [electric power transmission network](#) to recover from a total or partial shutdown.<sup>[36]</sup>

Normally, the electric power used within the plant is provided from the station's own generators. If all of the plant's main generators are shut down, station service power is

provided by drawing power from the grid through the plant's transmission line. However, during a wide-area outage, off-site power from the grid is not available. In the absence of grid power, a so-called black start needs to be performed to [bootstrap](#) the power grid into operation.

To provide a black start, some power stations have small [diesel generators](#), normally called the *black start diesel generator* (BSDG), which can be used to start larger generators (of several [megawatts](#) capacity), which in turn can be used to start the main power station generators. Generating plants using steam turbines require station service power of up to 10% of their capacity for [boiler feedwater pumps](#), boiler forced-draft combustion air blowers, and for fuel preparation. It is uneconomical to provide such a large standby capacity at each station, so black-start power must be provided over designated tie lines from another station. Often hydroelectric power plants are designated as the black-start sources to restore network interconnections. A hydroelectric station needs very little initial power to start (just enough to open the intake gates and provide [excitation](#) current to the generator field coils), and can put a large block of power on line very quickly to allow start-up of fossil-fuel or nuclear stations. Certain types of [combustion turbine](#) can be configured for black start, providing another option in places without suitable hydroelectric plants.<sup>[37]</sup> In 2017 a utility in Southern California has successfully demonstrated the use of a battery energy storage system to provide a black start, firing up a combined cycle gas turbine from an idle state.<sup>[38]</sup>

## Obsolescence

Despite novel institutional arrangements and network designs, power delivery infrastructures is experiencing aging across the developed world. Contributing factors include:

- Aging equipment – older equipment has higher [failure rates](#), leading to customer interruption rates affecting the economy and society; also, older assets and facilities lead to higher inspection [maintenance](#) costs and further [repair](#) and [restoration](#) costs.
- Obsolete system layout – older areas require serious additional substation sites and [rights-of-way](#) that cannot be obtained in the current area and are forced to use existing, insufficient facilities.
- Outdated engineering – traditional tools for [power delivery](#) planning and engineering are ineffective in addressing current problems of aged equipment, obsolete system layouts, and modern deregulated loading levels.
- Old cultural value – [planning](#), [engineering](#), operating of system using concepts and procedures that worked in vertically integrated industry exacerbate the problem under a deregulated industry.<sup>[39]</sup>

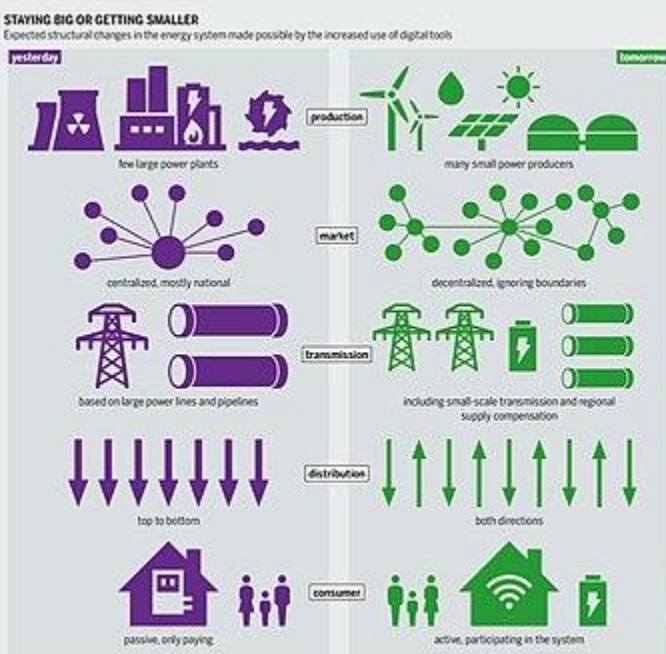
## Trends

## Demand response

[Demand response](#) is a grid management technique where retail or wholesale customers are requested or incentivised either electronically or manually to reduce their load. Currently, transmission grid operators use demand response to request load reduction from major energy users such as industrial plants.<sup>[40]</sup> Technologies such as smart metering can encourage customers to use power when electricity is plentiful by allowing for variable pricing.

## Smart grid

This section is an excerpt from [Smart grid](#).<sup>[edit]</sup>



Characteristics of a traditional centralized electrical system (left) vis-à-vis those of a smart grid (right)

The [smart grid](#) is an enhancement of the 20th century electrical grid, using two-way communications and distributed so-called intelligent devices.<sup>[41]</sup> Two-way flows of electricity and information could improve the delivery network. Research is mainly focused on three systems of a smart grid – the infrastructure system, the management system, and the protection system.<sup>[42]</sup> Electronic power conditioning and control of the production and distribution of electricity are important aspects of the smart grid.<sup>[43]</sup>

The smart grid represents the full suite of current and proposed responses to the challenges of electricity supply. Numerous contributions to the overall improvement of energy infrastructure efficiency are anticipated from the deployment of smart grid technology, in particular including [demand-side management](#). The improved flexibility of the smart grid permits greater penetration of highly variable renewable energy sources such as [solar](#)

[power](#) and [wind power](#), even without the addition of [energy storage](#). Smart grids could also monitor/control residential devices that are noncritical during periods of peak power consumption, and return their function during nonpeak hours.<sup>[44]</sup>

A smart grid includes a variety of operation and energy measures:

- [Advanced metering infrastructure](#) (of which [smart meters](#) are a generic name for any utility side device even if it is more capable e.g. a fiber optic router)
- Smart [distribution boards](#) and [circuit breakers](#) integrated with [home control](#) and [demand response](#) (*behind the meter* from a utility perspective)
  - [Load control switches](#) and [smart appliances](#), often financed by efficiency gains on municipal programs (e.g. [PACE financing](#))
- [Renewable energy](#) resources, including the capacity to charge parked ([electric vehicle](#)) batteries or larger arrays of batteries recycled from these, or other [energy storage](#).
- Energy efficient resources
- Electric surplus distribution by power lines and auto-smart switch
- Sufficient utility grade fiber [broadband](#) to connect and monitor the above, with wireless as a backup. Sufficient spare if "dark" capacity to ensure failover, often leased for revenue.<sup>[45][46]</sup>

Concerns with smart grid technology mostly focus on smart meters, items enabled by them, and general security issues. Roll-out of smart grid technology also implies a fundamental re-engineering of the electricity services industry, although typical usage of the term is focused on the technical infrastructure.<sup>[47]</sup>

Smart grid policy is organized in Europe as Smart Grid European Technology Platform.<sup>[48]</sup> Policy in the United States is described in [Title 42 of the United States Code](#).<sup>[49]</sup>

Grid defection

Resistance to distributed generation among grid operators may encourage providers to leave the grid and instead distribute power to smaller geographies.<sup>[50][51][52]</sup>

The [Rocky Mountain Institute](#)<sup>[53]</sup> and other studies<sup>[54]</sup> foresee widescale grid defection. However, grid defection may be less likely in places such as Germany that have greater power demands in the winter.<sup>[55]</sup>

History

Early electric energy was produced near the device or service requiring that energy. In the 1880s, electricity competed with steam, hydraulics, and especially [coal gas](#). Coal gas was first produced on customer's premises but later evolved into [gasification](#) plants that enjoyed [economies of scale](#). In the industrialized world, cities had networks of piped gas, used for

lighting. But gas lamps produced poor light, wasted heat, made rooms hot and smoky, and gave off [hydrogen](#) and [carbon monoxide](#). They also posed a fire hazard. In the 1880s electric lighting soon became advantageous compared to gas lighting.

[Electric utility](#) companies established [central stations](#) to take advantage of economies of scale and moved to centralized power generation, distribution, and system management.<sup>[56]</sup> After the [war of the currents](#) was settled in favor of [AC power](#), with long-distance power transmission it became possible to interconnect stations to balance the loads and improve load factors. Historically, transmission and distribution lines were owned by the same company, but starting in the 1990s, many countries have [liberalized](#) the regulation of the [electricity market](#) in ways that have led to the separation of the electricity transmission business from the distribution business.<sup>[57]</sup>

In the United Kingdom, [Charles Merz](#), of the [Merz & McLellan](#) consulting partnership, built the [Neptune Bank Power Station](#) near [Newcastle upon Tyne](#) in 1901,<sup>[58]</sup> and by 1912 had developed into the largest integrated power system in Europe.<sup>[59]</sup> Merz was appointed head of a parliamentary committee and his findings led to the Williamson Report of 1918, which in turn created the [Electricity \(Supply\) Act 1919](#). The bill was the first step towards an integrated electricity system. In 1925 the [Weir](#) Committee recommended the creation of a "national gridiron" and so the [Electricity \(Supply\) Act 1926](#) created the [Central Electricity Board](#) (CEB).<sup>[60]</sup> The CEB standardized the nation's electricity supply and established the first synchronized AC grid, running at 132 kilovolts and 50 [hertz](#) but initially operated as regional grids. After brief overnight interconnection in 1937 they permanently and officially joined in 1938 becoming the [UK National Grid](#).

In France, [electrification](#) began in the 1900s, with 700 [communes](#) in 1919, and 36,528 in 1938. At the same time, these close networks began to interconnect: Paris in 1907 at 12 kV, the Pyrénées in 1923 at 150 kV, and finally almost all of the country interconnected by 1938 at 220 kV. In 1946, the grid was the world's most dense. That year the state nationalised the industry, by uniting the private companies as [Électricité de France](#). The frequency was standardised at 50 Hz, and the 225 kV network replaced 110 kV and 120 kV. Since 1956, service voltage has been standardised at 220/380 V, replacing the previous 127/220 V. During the 1970s, the 400 kV network, the new European standard, was implemented. Starting on May 29, 1986, the end user service voltage will progressively change to 230/400 V +/-10%.<sup>[61][62]</sup>

In the United States in the 1920s, utilities formed joint-operations to share peak load coverage and backup power. In 1934, with the passage of the [Public Utility Holding Company Act](#) (USA), electric utilities were recognized as [public goods](#) of importance and were given outlined restrictions and regulatory oversight of their operations. The [Energy Policy Act of 1992](#) required transmission line owners to allow electric generation companies open access to their network<sup>[56][63]</sup> and led to a restructuring of how the electric industry operated in an effort to create competition in power generation. No longer were electric utilities built as vertical monopolies, where generation, transmission and distribution were

handled by a single company. Now, the three stages could be split among various companies, in an effort to provide fair access to high voltage transmission.<sup>[20][21]</sup> The [Energy Policy Act of 2005](#) allowed incentives and loan guarantees for alternative energy production and advance innovative technologies that avoided [greenhouse emissions](#).

In China, electrification began in the 1950s.<sup>[64]</sup> In August 1961, the electrification of the Baoji-Fengzhou section of the [Baocheng Railway](#) was completed and delivered for operation, becoming China's first [electrified railway](#).<sup>[65]</sup> From 1958 to 1998, China's electrified railway reached 6,200 miles (10,000 kilometres).<sup>[66]</sup> As of the end of 2017, this number has reached 54,000 miles (87,000 kilometres).<sup>[67]</sup> In the current [railway electrification system](#) of China, [State Grid Corporation of China—Archived](#) 2021-12-21 at the [Wayback Machine](#)—is an important power supplier. In 2019, it completed the power supply project of China's important electrified railways in its operating areas, such as [Jingtong Railway](#), [Haoji Railway](#), [Zhengzhou–Wanzhou high-speed railway](#), et cetera, providing power supply guarantee for 110 traction stations, and its cumulative power line construction length reached 6,586 kilometres.<sup>[68]</sup>

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National Energy Regulator of South Africa



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## Appearance

## Text

- 


 Small

 Standard

☐ Large

## Width

- 

 Standard

☐ Wide

Color (beta)

•

☐ Automatic

☐ Light

☐ Dark

From Wikipedia, the free encyclopedia

National Energy Regulator of South Africa



#### Agency overview

Formed	2005; 20 years ago
Jurisdiction	South Africa
Headquarters	Kulawula House, 526 Madiba Street, <a href="#">Arcadia, Pretoria</a> <ul style="list-style-type: none"><li>Thembani Bukula, Chairperson</li></ul>
Agency executives	<ul style="list-style-type: none"><li>Nomalanga Sithole, CEO</li></ul>
Website	<a href="https://www.nersa.org.za/">https://www.nersa.org.za/</a>

National Energy Regulator of South Africa (NERSA), is the regulatory authority for the electricity supply industry in [South Africa](#).<sup>[1]</sup>

#### Background

National Energy Regulator of South Africa was established to regulate the energy industry in South Africa and to follow government standards, laws, policies and international best practices in support of sustainable development.<sup>[2][3][4]</sup> It was established by the section 3 of the National Energy Regulator Act, 2004 (Act No. 40 of 2004). NERSA's mandate is to regulate the electricity, piped-gas and petroleum pipelines industries in terms of the 2001 Gas Act, Petroleum Pipelines act of 2003 and the Electricity Regulation Act..<sup>[5][6]</sup>

In November 2020, NERSA announced it was approving the procurement of 2,500 megawatts of nuclear power by the Department of Mineral Resources and Energy

skom



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#### Tools

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#### Appearance

##### Text

- 



Small



Standard



Large

##### Width

-

☐ Standard

☐ Wide

Color (beta)

•

☐ Automatic

☐ Light

☐ Dark

From Wikipedia, the free encyclopedia

Not to be confused with other similarly-named but unrelated businesses known as [Escom](#).

Eskom



Company type

[Public utility](#)

[Traded as](#)

[JSE: BIESKM](#)

Industry

[Energy](#)

Founded

1 March 1923; 101 years ago

Headquarters

[Sunninghill](#), [Sandton](#), [South Africa](#)

Key people

- Mteto Nyati (Chairman)
- Dan Marokane (Group Chief Executive)
- Calib Cassim (Chief Financial Officer)

Services

Electricity generation, transmission and distribution

Revenue

▲[R](#) 204.3 billion (FY2021)<sup>[1]</sup>

[US\\$](#) 13.82 billion

[Net income](#)

▲[R](#) -18.9 billion (FY2021)<sup>[1]</sup>

[US\\$](#) -1.28 billion

[Total assets](#)

▲[R](#) 781 billion (FY2021)<sup>[1]</sup>

[US\\$](#) 52.84 billion

Number of employees

▼42,749 (FY2021)<sup>[1]</sup>

[Subsidiaries](#)

List

[ASN](#)

- [37121](#)

Website

[www.eskom.co.za](http://www.eskom.co.za)

Eskom Hld SOC Ltd or Eskom is a South African electricity [public utility](#). Eskom was established in 1923 as the Electricity Supply Commission (ESCOM) ([Afrikaans: Elektrisiteitsvoorsieningskommissie \(EVKOM\)](#)). Eskom represents [South Africa](#) in the [Southern African Power Pool](#). The utility is the largest producer of electricity in [Africa](#),<sup>[2][3]</sup> and was among the top utilities in the world in terms of generation capacity and sales. It is the largest of [South Africa's state owned enterprises](#). Eskom operates a number of notable [power stations](#), including [Matimba Power Station](#) and [Medupi Power Station](#) in [Lephalale](#), [Kusile Power Station](#) in [Witbank](#), [Kendal Power Station](#), and [Koeberg Nuclear Power Station](#) in the Western Cape Province, the only nuclear power plant in Africa.

The company is divided into Generation, Transmission and Distribution divisions, and together Eskom generates approximately 95% of electricity used in South Africa, amounting to ~45% used in Africa,<sup>[4]</sup> and emits 42% of South Africa's total [greenhouse gas emissions](#).<sup>[5][6][7][8]</sup> By releasing 1.6 million tons of [sulphur dioxide](#) into the air in 2019, Eskom is also the largest emitter of sulphur dioxide in the power industry in the world.<sup>[9]</sup> Eskom has periodically implemented [rolling blackouts](#) since January 2008, a practice ascribed to basic dereliction of duty by former president [Thabo Mbeki](#).<sup>[10]</sup> Implementation of new [generating capacity](#) during this period was fraught with [delays](#) and [cost overruns](#) which brought the utility to the brink of bankruptcy.<sup>[11]</sup> In 2019, it was announced that Eskom was to be [split up](#) into three distinct nationally owned entities due to huge debts and poor reliability of supply.<sup>[12]</sup>

At the [2021 United Nations Climate Change Conference](#), a deal was announced for developed countries to fund South Africa's transition from coal power to [renewable energy](#). However, employment in the mining sector threatens this transition.<sup>[13]</sup>

History



The Congella Power Station completed in 1928 was one

of the first power plants built and owned by Eskom.

Prior to the establishment of Eskom, the provision of electricity was dominated by municipalities and private companies. The city of [Kimberley](#) was one of the first users of public electricity when it installed electric streetlights in 1882 to [reduce crime at night](#).<sup>[14]:5[15]</sup> This was followed by [Cape Town](#) in 1895 with the construction of the [Graaff Electric Lighting Works](#) to power 775 street lights.

Eskom was founded by the [Electricity Act of 1922](#) which allowed the South African Electricity Control Board to appoint [Hendrik Johannes van der Bijl](#) as chairman.<sup>[16]</sup> The company changed its name by combining the two acronyms in its previous name (ESCOM and ESKOM) in 1987 to become known as Eskom.

The Electricity Act stated that Eskom could only sell electricity at cost and was exempted from tax with the firm initially raising capital through the issuing of [debentures](#), later issuing state-guaranteed loans instead. The coal-fired [Congella Power Station](#) in [Durban](#) and [Salt River Power Station](#) in Cape Town were the first power stations built by Eskom, both completed in mid-1928.<sup>[17]</sup>

One of Eskom's first power plants was a coal-fired 128 MW station in [Witbank](#), completed in 1935 to provide power to the mining industry. The plant was built and run in partnership with the privately owned [Victoria Falls and Transvaal Power Company](#), which owned a number of other power plants across the country. Thanks to state support, Eskom was able to buy out the Victoria Falls and Transvaal Power Company in 1948 for £14.5 million (roughly equivalent to £2.55 billion in 2017). Following [World War 2](#), South Africa experienced power shortages that led to Eskom negotiating power saving agreements with the mining industry in June 1948.<sup>[14]:6</sup>

First expansion period: 1960-1994



[Arnot Power Station](#) completed in 1975 was one of the first of the "six-pack" coal-fired power plants built during this period that Eskom was well known for.

From 1960 to 1990 Eskom increased its installed power production capacity from 4,000 MW to 40,000 MW so as to keep up with rapid economic growth in the 1960s and 70s.<sup>[14]:4</sup> During the same period, Eskom established a nationwide 400 kV power network. During this

period the company built a number of large standardised coal-fired power plants that could produce power at very low cost due to the large [economies of scale](#). These plants were known colloquially as "six-packs" for the 6 large generator units they were designed to accommodate.<sup>[14]:7</sup>

In 1974 the company was instructed to start work on [Koeberg nuclear power station](#) to both provide power to Cape Town and help facilitate the [South African government's nuclear program](#).<sup>[14]:7</sup>

In 1981 Eskom was involved in one of its first large financial scandals when its Assistant Chief Accountant was caught embezzling R8 million from the company<sup>[14]:7</sup> (equivalent to roughly R164.37 million in 2018).<sup>[18]</sup>

During the 1970s the company controversially sought to increase electrical tariffs to help pay for its large expansion plans. Due to its financial situation, the government appointed Dr. W.J. de Villiers to chair a commission that recommended a number of financial and organisational changes for the company to adopt. This led to the company abandoning its no-profit objective and to raise funds by taking out international loans. The number of Eskom employees was also reduced from 66,000 to 60,000 in the late-1980s.<sup>[14]:8</sup>

Post-1994 election period: 1994-2007

Following [democratic elections in 1994](#) and the start of the [Mandela](#) government the company changed focus to electrification of previously neglected residential homes and to provide low cost electricity for economic growth. Following the passing of the 1998 [Eskom Amendment Act](#) government's powers to influence company policy and investment decisions were greatly expanded.<sup>[14]:8-9</sup> Due to the South African government's attempted privatisation of Eskom in the late 1990s during the administration of President [Thabo Mbeki](#), Eskom requests for budget to build new stations were denied. After leaving the presidency, Mbeki would later state in December 2007 that this was an error, resulting in adverse affects for the South African economy.<sup>[19]</sup>



Construction work on the [Medupi](#) (pictured) and [Kusile](#) coal-fired power stations was started in the 2007-2019 period as part of Eskom's capacity expansion program following the energy crisis.

Load shedding and second expansion: 2007-present

See also: [South African energy crisis](#)

In February 2006, Eskom announced "load shedding" in the Western Cape province, due to issues experienced by Koeberg Nuclear Power Plant<sup>[20]</sup> this continued until June 2006. In January 2008, Eskom controversially introduced load shedding nationally ([rolling blackouts](#)) based on a rotating schedule, in periods where short supply threatened the integrity of the grid. Demand-side management has focused on encouraging consumers to conserve power during peak periods in order to reduce the incidence of load shedding. Following the national power shortage in 2007, Eskom embarked on an aggressive electricity production expansion programme during the administration of President [Jacob Zuma](#). The Zuma administration decided to focus expansion efforts on building additional large scale six-pack coal-fired power plants.<sup>[21]</sup>

In 2016, Eskom stated it intended to pursue a nuclear solution to the country's energy shortage. According to projections from late 2016, the use of nuclear power would provide over 1000GW of power by 2050. In preparation, the company launched a training program for 100 technicians, engineers and artisans that would certify them as nuclear operators.<sup>[22]</sup> In January 2018, Eskom's acting chief financial officer stated that the company could not afford a new build, following a 34% drop in interim profits due to declining sales and increasing financing costs. The government stated it would proceed with the plan but more slowly.<sup>[23]</sup>

In 2017, Eskom was the focus of a major [corruption scandal](#) involving the [Gupta family](#) and the administration of then President Jacob Zuma.

The [National Energy Regulator of South Africa](#) denied an application by Eskom to increase electricity tariffs by a future 19.9% for the financial year 2018/19. The regulator instead granted a 5.2% increase and gave a list of reasons for the refusal to grant higher tariffs that the South African newspaper [Business Day](#) stated painted "a picture of inefficiency, inaccurate forecasting and cost overruns" at the power utility. Part of the refusal was the finding that Eskom had 6,000 more employees than needed, costing the company R3.8 billion annually.<sup>[24]</sup>

In February 2019, shortly after the announcement by government that the company would be broken up, Eskom initiated another round of emergency load shedding. Eskom stated that the 2019 load shedding was initiated due to breakdowns at power stations as well as the depletion of water and diesel resources. Other reasons cited included legacy issues from [state capture](#) corruption, coal availability, and that new power plants such as [Medupi](#) and [Kusile](#) were not yet operational.<sup>[25][26]</sup> Corruption during the Zuma administration had been noted as a major factor in the cost overruns and long delays in completing Medupi and Kusile power plants that had a knock-on effect leading to the 2019 power shortages.<sup>[26]</sup> The power shortage and related troubles at Eskom was blamed as a significant contributing factor to a 3.2% decline in GDP growth in the first quarter of 2019,<sup>[27]</sup> prompting fears of a [recession](#) in 2019.<sup>[28]</sup> In December 2019, President [Ramaphosa](#), deputy president [David](#)

[Mabuza](#) and Ministers [Gwede Mantashe](#) and [Pravin Gordhan](#) met with Eskom's board and management to discuss about the energy crises.<sup>[29]</sup> The president attributed the recent blackouts partly to sabotage at the [Tutuka Power Station](#) in [Mpumalanga](#) which had caused a loss of 2000 megawatts of electricity,<sup>[30]</sup> and announced measures to bring an end to load-shedding. Mantashe and Gordhan were tasked with presenting ways to increase electricity capacity to the cabinet, which would include self-generation.<sup>[31]</sup> Amid the crisis, [Jabu Mabuza](#) resigned from his post as chairperson of Eskom's board in January 2020.<sup>[32]</sup> Between March and July 2020 the power supply was stable due to reduced demand during the [COVID-19 lockdown](#),<sup>[33]</sup> but on 12 July a new round of level 2 load shedding began due to the breakdown of generating units.<sup>[34]</sup> During the winter of 2023, the country experienced Stage 6 blackouts, shaving a projected 2% off the country's GDP.<sup>[35]</sup> During the worst period, power cuts lasted 12 hours a day.<sup>[36]</sup> The company faces theft of materials for resale, sabotage to force repairs to be made at corruptly inflated prices, and assassination attempts which may be motivated by the attempt to replace coal with renewable sources.<sup>[37]</sup>

## Logos

Eskom's logo has been an integral symbol of the company since its founding. For a brief period in 1986 Eskom had no logo when it was moving away from the company's original logo of stylised letters spelling "ESC" within a circle to the more contemporary version with a blue shield with a stylised lightning bolt in its centre. The 1987 logo was replaced in 2002 with its current logo that replaced the shield with a circle but otherwise kept the logo as it was.



1923



1987



2002

#### Restructuring efforts

Eskom's sales have been declining by about 1% per annum. The less it sells, the higher the tariff it wants, and the less it sells – the utility death spiral.

*Rod Crompton, Adjunct professor African Energy Leadership Centre Wits Business School, University of the Witwatersrand*<sup>[38]</sup>

In December 1998, a [white paper](#) prepared by the Department of Minerals and Energy recommended that the government restructure Eskom into separate generation and transmission businesses. Although the report predicted that this action would improve power supply and reliability, it was never enacted.<sup>[39]</sup>

In February 2019, these plans were resurrected during the [State of the Nation address](#). President [Ramaphosa](#) announced that the government would be splitting Eskom up into three new state-owned entities focusing on generation, transmission and distribution.<sup>[12]</sup> This was done so as to better manage the serious operational and financial problems facing the company. By the time of the speech Eskom had a total debt burden of R419 billion<sup>[12]</sup> (US\$30.8 billion) and was entering a death spiral whereby there was not enough revenue to make debt repayments.<sup>[38]</sup>

In a February 2019 briefing, the [Department of Public Enterprises](#) stated that Eskom was "[technically insolvent](#)" and would not be able to operate past the next three months if it did not receive additional loans.<sup>[40]</sup> Finance Minister [Tito Mboweni](#) then announced in his 2019 budget speech that government would be providing a R69 billion rand (US\$5 billion) bail-out to Eskom over a three-year period so as to stabilise the company's serious financial situation.<sup>[41]</sup>

#### Transmission

Main article: [National Transmission Company of South Africa](#)

As result of the restructuring, a transmission entity called the National Transmission Company of South Africa (NTCSA), a wholly-owned subsidiary of Eskom, would be given its own board, by 31 March 2020 in which the transmission legal entity would be responsible for hearing legislative amendments in accordance to government law. This new

transmission entity would involve up to 6,000 people that are responsible of setting up thousands of kilometres of "wires" and transmission lines that would ensure electricity from the power stations to where power is needed.<sup>[42]</sup> As part of the Transmission Development Plan (TDP) for 2020–2029 Eskom has plans to increase its transmission infrastructure by approximately 4,800 km of extra high voltage transmission lines, and over 35,000 MVA of transformer capacity over the next 10 years. This new outline of reconstructing Eskom comes from new regulatory guidelines from the National Energy Regulator of South Africa (NERSA) to publish an annual TDP report. <sup>[citation needed]</sup>

In July 2023, NERSA approved for the National Transmission Company of South Africa to operate a transmission system in South Africa.<sup>[43]</sup> In September 2023, NERSA approved the remaining trading and import/export licences.<sup>[44]</sup>

#### COSATU response

In response to feared job losses resulting from the breakup the trade union [COSATU](#) organised a national strike and called for a moratorium on retrenchments in the private and public sectors.<sup>[45][46][47]</sup> This caused to the apparent abandonment of the government's company breakup and restructuring plans.<sup>[46][48]</sup> In July 2019 the outgoing Eskom CEO announced that Eskom had entered a "death spiral" and highlighted the need for the company to restructure.<sup>[48][49]</sup> Following the appointment of [André de Ruyter](#) as Eskom CEO trade unions [National Union of Mineworkers](#) and [Solidarity](#) stated that they would fight any government restructuring efforts that might result in job losses.<sup>[50]</sup>

In December 2019 COSATU suggested that money be used from the [Public Investment Corporation](#) (PIC) to reduce Eskom's debt from around R450 billion to more manageable levels.<sup>[51]</sup> In return COSTATU proposed a number of conditions that included keeping workers employed.<sup>[52]</sup> The trade union Solidarity was strongly apposed to the COSATU proposal arguing that it put the pensions of public employees at risk.<sup>[53]</sup> The country's second biggest trade union, the [Federation of Unions of South Africa](#), was also skeptical of COSATU's proposed plan.<sup>[54]</sup>

#### Job losses

Between 2020 and 2021, two thousand employees lost their jobs at the power utility. 6000 more jobs are reportedly at risk in order for the company to continue operating.<sup>[55]</sup>

#### Installed capacity

Main article: [List of power stations in South Africa](#)

#### Subscribers

Eskom – the only electricity utility in the country – has 16,789,974 subscribers in South

Africa, comprising about one-third of the population.

#### Fossil-fuelled power stations

Power plant	Province	Type	Date commissioned (planned)	Capacity (MW) (planned)	Status	Notes
<a href="#">Acacia Power Station</a>	Western Cape	<a href="#">Gas turbine</a>	1976	171	Operational	<a href="#">[56]</a> <a href="#">[permanent dead link]</a>
<a href="#">Ankerlig Power Station</a>	Western Cape	Gas turbine	2007	1,338	Operational	<a href="#">[57]</a>
<a href="#">Arnot Power Station</a>	Mpumalanga	<a href="#">Coal-fired</a>	1971-1975	2,352	Operational	<a href="#">[58]</a> <a href="#">[59]</a>
<a href="#">Camden Power Station</a>	Mpumalanga	Coal-fired	1967-1969; 2005-2008	1,561	Operational	<a href="#">[59]</a> <a href="#">[60]</a>
<a href="#">Duvha Power Station</a>	Mpumalanga	Coal-fired	1980-1984	3,600	Operational	<a href="#">[59]</a> <a href="#">[61]</a> <a href="#">[62]</a>
<a href="#">Gourikwa Power Station</a>	Western Cape	Gas turbine	2007	746	Operational	<a href="#">[57]</a>
<a href="#">Grootvlei Power Station</a>	Mpumalanga	Coal-fired	1969-1977; 2008-2011	1,180	Operational	<a href="#">[59]</a> <a href="#">[63]</a>
<a href="#">Hendrina Power Station</a>	Mpumalanga	Coal-fired	1970-1976	1,893	Operational	<a href="#">[59]</a> <a href="#">[64]</a>
<a href="#">Kendal Power Station</a>	Mpumalanga	Coal-fired	1988-1992	4,116	Operational	<a href="#">[59]</a> <a href="#">[65]</a> <a href="#">[66]</a>
<a href="#">Komati Power</a>	Mpumalanga	Coal-	1961-1966;	990	Operational	<a href="#">[59]</a> <a href="#">[67]</a>

<a href="#">Station</a>		fired	2009-2013			
<a href="#">Kriel Power Station</a>	Mpumalanga	Coal-fired	1976-1979	3,000	Operational	<a href="#">[59][68][69]</a>
<a href="#">Kusile Power Station</a>	Mpumalanga	Coal-fired	(2017–2025)	3,200 (4,800)	4/6 units operational	<a href="#">[70][71][72]</a> <a href="#">[73][74]</a>
<a href="#">Lethabo Power Station</a>	Free State	Coal-fired	1985-1990	3,708	Operational	<a href="#">[59][75]</a>
<a href="#">Majuba Power Station</a>	Mpumalanga	Coal-fired	1996–2001	4,110	Operational	<a href="#">[59][76][77]</a> <a href="#">[unreliable source?]</a>
<a href="#">Matimba Power Station</a>	Limpopo	Coal-fired	1987-1991	3,990	Operational	<a href="#">[59][78]</a>
<a href="#">Matla Power Station</a>	Mpumalanga	Coal-fired	1979-1983	3,600	Operational	<a href="#">[59][79]</a>
<a href="#">Medupi Power Station</a>	Limpopo	Coal-fired	2015–2019	4,764	Operational	<a href="#">[72][80][81]</a> <a href="#">[73][74]</a>
<a href="#">Port Rex Power Station</a>	Eastern Cape	Gas turbine	1976	171	Operational	<a href="#">[56]</a>
<a href="#">Tutuka Power Station</a>	Mpumalanga	Coal-fired	1985-1990	3,654	Operational	<a href="#">[59][82]</a>
Renewable and nuclear power stations						



Eskom Generation's pilot [wind farm](#) facility at [Klipheuwel](#) in the [Western Cape](#), [South Africa](#).

Power plant	Province	Type	Date commissioned	Installed capacity (MW)	Status	Notes
<a href="#">Colley Wobbles Power Station</a>	Eastern Cape	<a href="#">Hydroelectric</a>	1984	42	Operational	
<a href="#">Drakensberg Pumped Storage Scheme</a>	Free State	<a href="#">Hydroelectric</a>	1981	1,000	Operational	<a href="#">[83]</a>
<a href="#">Gariep Dam</a>	Free State-Eastern Cape border	<a href="#">Hydroelectric</a>	1971	360	Operational	<a href="#">[84]</a>
<a href="#">Ingula Pumped Storage Scheme</a>	KwaZulu-Natal	<a href="#">Hydroelectric</a>	2017	1,332	Operational	<a href="#">[73]</a> <a href="#">[85]</a>
<a href="#">Koeberg Power Station</a>	Western Cape	<a href="#">Nuclear</a>	1984	1,860	Operational	<a href="#">[86]</a> <a href="#">[87]</a>
<a href="#">Ncora Dam</a>	Eastern Cape	<a href="#">Hydroelectric</a>	1972	2.1	Operational	<a href="#">[88]</a>
<a href="#">Palmiet Pumped Storage Scheme</a>	Western Cape	<a href="#">Hydroelectric</a>	1988	400	Operational	<a href="#">[89]</a> <a href="#">[90]</a>
<a href="#">Sere Wind Farm</a>	Western Cape	<a href="#">Wind</a>	Jan 2015	100	Operational	<a href="#">[91]</a> <a href="#">[92]</a> <a href="#">[93]</a> <a href="#">[94]</a>
<a href="#">Vanderkloof Dam</a>	Northern Cape	<a href="#">Hydroelectric</a>	1977	240	Operational	

## Future projects

Eskom has a number of planned infrastructure projects to further expand electrical production.

- Tubatse Pumped Storage Scheme – 1500MWe
- Wind 500 – 550MWe
- Tasakoolo Wind farm 200 – 200Mwe

## Investment in renewables

As of October 2019 Eskom Holdings SOC Ltd issued a tender to introduce 20 three-phase KW inverters and mountains structures. These structures are planned to distribute power to four power plants, and would introduce Eskom into the solar energy market. The African Investment Forum has announced that it has raised over \$40.1 billion in investment into developing new infrastructure, related to renewable energies.<sup>[95]</sup> This is aimed to help distance itself from Eskom coal power plants, and to focus more on wind and solar developments. The African investment forum is backed up by corporate organizations and lenders, private donors, and the African Development Bank.<sup>[96]</sup>

These new inverters would be align with South Africa's Integrated Resource Plan (IRP).<sup>[citation needed]</sup>

## South Africa's integrated resource plan

The IRP supports a diverse energy mix with policy aimed to help aim to meet the need of South Africa's energy goals. The Integrated Resource Plan supports electrical infrastructure developments with an aim focused on [renewable energy sources](#).<sup>[97]</sup> These new investments are directed towards more high efficiency, low emission standards with an emphasis on solar technologies in which 6,000 MW of new Solar PV capabilities and 14,400 MW of new wind power technologies.<sup>[98]</sup> With renewable energies, the IRP plans to increase its investment in hydro-electric power.<sup>[99]</sup>

## Investment in renewables, hydro, wind, solar

With failing power plants and coal not working as a viable solution, progress towards a greener future is in sight for South Africa. In agreement to the Paris Agreement, South Africa needs to reduce its carbon emission and cut-back from being dependent on Coal. There is new US\$11 Billion Green-Energy Initiative aimed at the development of solar and wind. This new initiative would allow loans to Eskom and below commercial rates on conditions that it would accelerate its closure of power plants and to start building renewable energy structures.<sup>[100]</sup> This plan takes the steps in moving away from coal, and

investing in alternative methods that better suit their needs for the future.<sup>[citation needed]</sup>

#### Other infrastructure

In 2002, Eskom was issued a network operator licence. It embarked on a \$100 million project installing [fibre optic cables](#) on 10 000 kilometres of its existing power lines for the purpose of real-time monitoring of the electrical network; 80% consists of all-dielectric lashed cabling and 10% [All-dielectric self-supporting cabling](#). It currently has the sixth most [ASN](#) prefixes of all registered network operator licensees.<sup>[101]</sup>

#### Corporate affairs



Eskom executives including Phakamani Hadebe (CEO), front row second from the left, and Jan Oberholzer (CTO), front row far left, at a 2019 public forum in Cape Town on Eskom's financial situation.

In 2011 eight out of ten Eskom board members were controversially sacked by the Zuma administration.<sup>[21]</sup> From 2015 to 2017 the Zuma administration appointed [Ben Ngubane](#) as chairperson of the board. [Brian Molefe](#) was appointed by Zuma as Eskom CEO from April 2015 to November 2016. Molefe<sup>[102]</sup> and Ngubane's<sup>[103]</sup> tenure was controversial for their involvement with the [Gupta family](#) and for allegedly allowing the company to become a vehicle for [state capture](#).<sup>[104][105][106][107]</sup> Ngubane also controversially attempted to blacklist newspapers perceived as unfriendly to Eskom.<sup>[103]</sup> During parliament's state capture inquiry in 2017 former Eskom chairperson Zola Tsotsi (2012–2015) testified that Gupta family member Tony Gupta made threats against Tsotsi allegedly stating that Tsotsi will lose his job as he was not 'helping' the Guptas.<sup>[108]</sup> In December 2016, [Matshela Koko](#), former head of generation for Eskom, was named as acting CEO.<sup>[109]</sup> He resigned in 2018 after being implicated in awarding contracts to a company linked to his stepdaughter.<sup>[110]</sup> Koko, along with his wife and stepdaughter, were arrested in October 2022.<sup>[111]</sup> In early 2018, following the establishment of the Ramaphosa government, multiple members of the Eskom board and executive team were replaced by government due to allegations of corruption and mismanagement.<sup>[112]</sup>

[Phakamani Hadebe](#) was made acting CEO and director of Eskom in May 2018 as part of President Ramaphosa's replacement of the company's executive team.<sup>[113]</sup> A year into his term as CEO Hadebe resigned citing poor health and the difficult circumstances of the

job.<sup>[114]</sup> His resignation sparked a debate amongst political parties over the difficult state of managing the financially strained state owned company<sup>[115]</sup> as well as the lack of political cover he was given to deal with labour unions and tackle corruption.<sup>[116]</sup>

Six months after Hadebe's departure, former [Nampak](#) Chief Executive<sup>[117]</sup> [André de Ruyter](#) was appointed CEO of Eskom.<sup>[118][119]</sup> De Ruyter's appointment was criticised by the [EFF](#)<sup>[120]</sup> and factions within the [ANC](#) who instead wanted a [black](#) CEO appointed to the position.<sup>[121]</sup> De Ruyter resigned in December 2022 after repeated attacks on him by [Gwede Mantashe](#), [Minister of Mineral Resources and Energy](#)<sup>[122][123][124]</sup> partly due to de Ruyter's advocacy for replacing coal with [renewables](#) as an energy source.<sup>[125]</sup> [News24](#) reported that he was not given the support needed to succeed in the position.<sup>[126]</sup> Shortly after the announcement that de Ruyter would be leaving Eskom it was reported that he survived a poisoning attempt after he unknowingly drank a cup of coffee at his office that was laced with [cyanide](#).<sup>[127]</sup>

#### Financials

	2011 <a href="#">[128]</a>	2012 <a href="#">[129]</a>	2013 <a href="#">[129]</a>	2014 <a href="#">[130]</a>	2015 <a href="#">[130]</a>	2016 <a href="#">[131]</a>	2017 <a href="#">[131]</a>	2018 <a href="#">[132]</a>	2019 <a href="#">[133]</a>	2020 <a href="#">[1]</a>	2021 <a href="#">[1]</a>
Revenue (R billion)	91.45	114.8	128.9	138.3	147.7	164.2	177.1	177.4	179.8	199.5	204.3
<a href="#">Operating profit</a> (R billion)	14.5	22.3	3.99	13.2	11.1	15.7	15.5	20.5	-1.77	4.41	6.68
<a href="#">Net income</a> (R billion)	8.36	13.2	5.18	7.09	3.62	5.15	0.88	-2.33	-20.7	-20.8	-18.9
Total debt (R billion)	160.3	182.6	202.9	254.8	297.4	322.7	355.3	388.7	440.6	483.7	401.8

Employee benefit expenses (R billion)	16.7	20.2	23.6	25.6	25.9	29.2	33.1	29.4	33.3	33.2	32.9
Number of employees	41,778	43,473	46,266	46,919	46,490	47,978	47,658	48,628	46,665	44,772	42,749
Electrical output capacity (GWh)	237,430	237,414	232,228	231,129	226,300	238,599	220,166	221,936	218,939	214,968	201,400

In 2018 and 2019 Eskom's negative financial situation became serious as costs started exceeding income and the company started experiencing trouble raising money. For 72 hours between 26 March and 29 March 2019 it was reported that Eskom had run out of funds thereby threatening to negatively impact the broader South African economy. The situation was alleviated once Eskom secured a R3 billion commercial loan which was paid back on 2 April after the Reserve Bank disbursed R5 billion to Eskom through an emergency provision.<sup>[134]</sup> In July 2019 Eskom announced a loss of R20.7 billion due to the cost of servicing high levels of debt, the increased cost of primary energy and unpaid municipal debts.<sup>[135]</sup>

#### Debt

In late 2016, [Standard & Poor's Global Ratings](#) downgraded Eskom's [credit rating](#) further into subinvestment grade cutting its long-term credit rating to BB – two levels below the investment threshold.<sup>[136]</sup> By 2017 increasing levels of debt and corruption scandals affecting the company has led investment bank [Goldman Sachs](#) to declare Eskom as being the "biggest risk to South Africa's economy." The company had R413 billion in debt and planned to raise an additional R340 billion (US\$26 billion) by 2022 thereby representing eight percent of South Africa's GDP. R218.2 billion of the company's debt consist of [government guarantees](#).<sup>[137]</sup> Exacerbating the company's financial situation was a recorded

R3 billion worth of irregular expenditures in 2017.<sup>[115]</sup>

On 28 March 2018 [Moody's Investors Service](#) downgraded Eskom's credit rating to B2 from B1 stating that it was concerned with "the lack of any tangible financial support for the company in the February state budget".<sup>[138]</sup>

On 24 November 2020, Moody's further downgraded Eskom's long-term credit rating to Caa1.<sup>[139]</sup> This places Eskom's credit within the "[speculative grade](#)" of investment, with a "very high credit risk".

Due to the company's large size and important role as the region's primary energy producer President Ramaphosa stated that Eskom was "[too big to fail](#)" as the reason why government had to continue to fund it despite its serious financial situation.<sup>[140]</sup>

In February 2023, with debt sitting at R423 billion, the South African government announced that, subject to approval from existing debt holders, it would be providing support worth R254 billion, including interest payments for the following three years and three capital payments of R78-billion in 2023/24, R66 billion in 2024/25 and R40-billion in 2025/26, with the intention to reduce Eskom's overall debt to R300 billion.<sup>[141]</sup>

#### Chinese debt

In July 2018 it was announced that Eskom had taken out a R33 billion loan from the Chinese government owned [China Development Bank](#).<sup>[142]</sup> The loan conditions were controversially<sup>[143]</sup> not made public with accusations that it was an example of [debt-trap diplomacy](#) by China.<sup>[144]</sup> During the [Zondo Commission of Inquiry](#) into state corruption a senior Eskom executive stated that an additional R25 billion loan from the China-based company Huarong Energy Africa was improperly and controversially taken out by Eskom.<sup>[145]</sup> After the loan had been issued Eskom chairperson Jabu Mabuza stated to the Zondo Commission that Eskom would not be repaying the Huarong loan due to irregularities and corruption involved in the issuing of the loan.<sup>[146]</sup>

#### Controversies

##### Municipal debts

A number of South African municipalities are in significant arrears in paying Eskom for electricity supplied to them. The large amount owed to Eskom has caused significant controversy given the state utilities financial difficulties and repeated periods of load-shedding.<sup>[147]</sup> By January 2020 South African municipalities owed Eskom a total of roughly R43 billion<sup>[148]</sup> (equivalent to US\$2.88 billion). This had increased to R49.1 billion by July 2022.<sup>[149]</sup>

## Soweto

The single largest South African municipality to owe Eskom for unpaid electricity is the [City of Johannesburg Metropolitan Municipality](#) in which Soweto owes R13 billion<sup>[150]</sup> to R16.4 billion<sup>[148]</sup> in 2019. In response, Eskom initiated a process of cutting off electricity to debtors in the city, which resulted in violent public protests.<sup>[151][152]</sup> The city has a history of non-payment dating back to the 1980s when non-payment was used as a form of non-violent protest against [apartheid](#) era policies.<sup>[153]</sup> This is thought to have cultivated a culture of non-payment.<sup>[150]</sup>

## Zimbabwe Power Exports

300MW of power are exported to Zimbabwe in a deal valued at US\$2 million a month. At the end of November 2019 it was revealed that Zimbabwe owed \$22 million in debt to Eskom (about 11 months in arrears). Despite statements that Eskom continues to supply Zimbabwe during scheduled blackouts,<sup>[154]</sup> electricity is only supplied if Eskom does not need it.<sup>[155][156]</sup>

Power shortage: 2007 - ongoing

See also: [South African energy crisis](#)



An election poster referring to the Eskom energy crisis in the run up to the 2019 general election.

In the later months of 2007, South Africa started experiencing widespread [rolling blackouts](#) as supply fell behind demand, threatening to destabilise the national grid. With a reserve margin estimated at 8% or below,<sup>[157]</sup> such "load shedding" is implemented whenever generating units are taken offline for maintenance, repairs or re-fuelling (in the case of nuclear units). From February 2008 to November 2014 blackouts were temporarily halted due to reduced demand and maintenance stabilization.<sup>[158]</sup> This drop in demand was caused by many of the country's mines shutting down or slowing to help alleviate the burden.

Load shedding was reintroduced in early November 2014. The Majuba power plant lost its capacity to generate power after a collapse of one of its coal storage silos on 1 November

2014. The Majuba power plant delivered approximately 10% of the country's entire capacity and the collapse halted the delivery of coal to the plant.<sup>[159]</sup> A second silo developed a major crack on 20 November causing the shut down of the plant again, this after temporary measures were instituted to deliver coal to the plant.<sup>[160]</sup>

In 2016, Eskom said that unplanned outages had been reduced. In May 2016, former president Jacob Zuma said assurances had been given to him by Eskom management.<sup>[161]</sup>

In June 2018, there was Stage 1 load shedding along with a strike over wages.<sup>[161]</sup>

In February 2019, a new round of load shedding began due to the failure of coal burning boilers at some power stations due to poor quality coal. This resulted in long running periods of level 4 load shedding across the country in mid-March 2019, including night-time load shedding<sup>[162]</sup> and promised to report back.<sup>[161]</sup> The situation at Eskom and resulting energy crisis became a political issue during the [2019 South African general elections](#).<sup>[163][164][165]</sup>

#### Sabotage

In December 2019, load shedding reached a new high as Eskom introduced stage 6 load shedding for the first time.<sup>[166]</sup> [Cyril Ramaphosa](#) faced criticism as his departure for Egypt was announced shortly after the move to stage 6.<sup>[167]</sup> He returned early to address the problem, meeting on 11 December with the Eskom board. Ramaphosa then announced that there had been an element of [sabotage](#) involved, leading to the loss of 2000MW capacity. Ramaphosa faced criticism on social media, with many blaming incompetence rather than sabotage.<sup>[168]</sup>

On 19 November 2021, Eskom announced that an initial forensic investigation found evidence that recent damage to a coal conveyor at Lethabo was the result of deliberate sabotage. Steel supports had been severed, causing a power supply pylon to collapse.<sup>[169][170]</sup> In a media briefing, de Ruyter commented that the matter had been referred to the [Hawks](#) for further investigation.<sup>[171]</sup> In May 2022 the Minister for Public Enterprises, [Pravin Gordhan](#), reported to Parliament that additional incidents of cables being cut intentionally by saboteurs, rising theft at its power plants, and corruption around the supply of fuel oil, had greatly worsened the energy crisis and Eskom's ability to resolve it.<sup>[172]</sup>

#### Corruption

##### 2017 corruption scandal

See also: [Gupta family](#)

Eskom was forced to suspend its chief financial officer Anoj Singh in July 2017 when the Development Bank of South Africa threatened to recall a R15 billion loan if no action was

taken against Eskom officials (including Singh) who were involved in corruption allegations involving the [Gupta family](#).<sup>[115]</sup> In September 2017, Minister for Public Enterprises, [Lynne Brown](#), instructed Eskom to take legal action against firms and individuals involved; ranging from Gupta family-owned consultancy firm Trillian Capital Partners Ltd. and consultancy firm [McKinsey](#) to Anoj Singh and acting chief executive Matshela Koko.

A report compiled by Eskom and G9 Forensic found that the two consulting firms including Gupta owned Trillian made R1.6 billion (US\$120 million) in fees with an additional R7.8 billion made from future contracts.<sup>[173]</sup> An investigation done by the amaBhungane Centre for Investigative Journalism found that the Gupta family had received contracts worth R11.7 billion from Eskom to supply coal between 2014 and 2017. With pressure for Eskom to sign the first coal supply contracts with Gupta-owned entities being applied on the state-owned firm by then President Jacob Zuma.<sup>[174]</sup> In 2019 South African [Special Investigating Unit](#) launched an investigation into corruption related to the construction of the Medupi and Kusile power stations as a cause of repeated construction delays and project cost increases;<sup>[175]</sup> this led to the investigation of 11 contractors for allegedly stealing R139 billion (US\$9.13 billion) from the projects.<sup>[175][176]</sup> In 2019, two senior Eskom managers and two business people were charged with fraud and corruption related to the construction of the Kusile power station.<sup>[177]</sup>

In January 2020 South African Minister for Public Enterprises, Pravin Gordhan, stated that cost overruns and corruption during the construction of Medupi and Kusile power stations was an important reason for the dramatic increase in Eskom electricity prices.<sup>[178]</sup>

#### 2019 Deloitte consulting lawsuit

In October 2019, Eskom's chairman [Jabu Mabuza](#) filed a court affidavit at the [Johannesburg High Court](#) to recover R207 million in consulting fees from the consulting firm [Deloitte](#). The affidavit alleged that Eskom executives had improperly awarded two consulting contracts to the consulting firm [Deloitte](#). According to Eskom, in one contract awarded to Deloitte, Deloitte proposed a fee of R88.8-million while the competing bids from other firms were for R14.6-million and R13.3-million. In the other contract, Deloitte's bid was R79.1-million, while the other bids were for R16-million and R9.1-million.<sup>[179]</sup>

In March 2020, Deloitte agreed to pay back R150 million of the R207 million sought by Eskom. However, in a joint statement, it denied being part of any corruption, and that they acknowledged that there were technical irregularities in the process of awarding the contracts.<sup>[180]</sup>

In April 2020, Deloitte told [AmaBhungane](#) that the managing director for Deloitte Africa's advisory division Thiru Pillay and the lead consultant on the Eskom contract Shamal Sivasanker had resigned effective 31 March 2020 for their roles in the Eskom event.<sup>[181]</sup>

In November 2021, Eskom announced that it had appointed Deloitte as its next external

auditor, as its contract with [Grant Thornton](#) was expiring at the end of that month.<sup>[182]</sup>

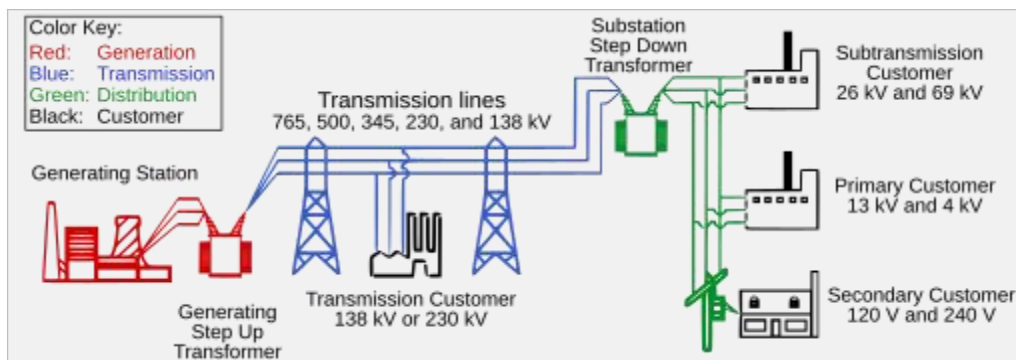
power transmission is the bulk movement of [electrical energy](#) from a [generating](#) site, such as a [power plant](#), to an [electrical substation](#). The interconnected lines that facilitate this movement form a *transmission network*. This is distinct from the local wiring between high-voltage substations and customers, which is typically referred to as [electric power distribution](#). The combined transmission and distribution network is part of [electricity delivery](#), known as the [electrical grid](#).

Efficient long-distance transmission of electric power requires high [voltages](#). This reduces the losses produced by strong [currents](#). Transmission lines use either [alternating current](#) (AC) or [direct current](#) (DC). The voltage level is changed with [transformers](#). The voltage is stepped up for transmission, then reduced for local distribution.

A [wide area synchronous grid](#), known as an *interconnection* in North America, directly connects generators delivering AC power with the same relative *frequency* to many consumers. North America has four major interconnections: [Western](#), [Eastern](#), [Quebec](#) and [Texas](#). [One grid connects most of continental Europe](#).

Historically, transmission and distribution lines were often owned by the same company, but starting in the 1990s, many countries [liberalized](#) the regulation of the [electricity market](#) in ways that led to separate companies handling transmission and distribution.<sup>[2]</sup>

System



A diagram of

an electric power system. The transmission system is in blue.

Most North American transmission lines are high-voltage [three-phase AC](#), although [single phase AC](#) is sometimes used in [railway electrification systems](#). DC technology is used for greater efficiency over longer distances, typically hundreds of miles. [High-voltage direct current](#) (HVDC) technology is also used in [submarine power cables](#) (typically longer than 30 miles (50 km)), and in the interchange of power between grids that are not mutually synchronized. HVDC links stabilize power distribution networks where sudden new loads, or blackouts, in one part of a network might otherwise result in synchronization problems and [cascading failures](#).

Electricity is transmitted at [high voltages](#) to reduce the energy loss due to [resistance](#) that occurs over long distances. Power is usually transmitted through [overhead power lines](#). [Underground power transmission](#) has a significantly higher installation cost and greater operational limitations, but lowers maintenance costs. Underground transmission is more common in urban areas or environmentally sensitive locations.

Electrical energy must typically be generated at the same rate at which it is consumed. A sophisticated control system is required to ensure that [power generation](#) closely matches demand. If demand exceeds supply, the imbalance can cause generation plant(s) and transmission equipment to automatically disconnect or shut down to prevent damage. In the worst case, this may lead to a cascading series of shutdowns and a major regional [blackout](#).

The US Northeast faced blackouts in [1965](#), [1977](#), [2003](#), and major blackouts in other US regions in [1996](#) and [2011](#). Electric transmission networks are interconnected into regional, national, and even continent-wide networks to reduce the risk of such a failure by providing multiple [redundant](#), alternative routes for power to flow should such shutdowns occur. Transmission companies determine the maximum reliable capacity of each line (ordinarily less than its physical or thermal limit) to ensure that spare capacity is available in the event of a failure in another part of the network.

Overhead

Main article: [Overhead power line](#)



A four-circuit, two-voltage power transmission line; Bundled 2-ways



A typical [ACSR](#). The conductor consists of seven strands of steel surrounded by four layers of aluminium.



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High-voltage overhead conductors are not covered by insulation. The conductor material is nearly always an [aluminium](#) alloy, formed of several strands and possibly reinforced with steel strands. Copper was sometimes used for overhead transmission, but aluminum is lighter, reduces yields only marginally and costs much less. Overhead conductors are supplied by several companies. Conductor material and shapes are regularly improved to increase capacity.

Conductor sizes range from 12 mm<sup>2</sup> (#6 [American wire gauge](#)) to 1,092 mm<sup>2</sup> (2,156,000 [circular mils](#) area), with varying resistance and [current-carrying capacity](#). For large conductors (more than a few centimetres in diameter), much of the current flow is concentrated near the surface due to the [skin effect](#). The center of the conductor carries little current but contributes weight and cost. Thus, multiple parallel cables (called [bundle conductors](#)) are used for higher capacity. Bundle conductors are used at high voltages to reduce energy loss caused by [corona discharge](#).

Today, transmission-level voltages are usually considered to be 110 kV and above. Lower voltages, such as 66 kV and 33 kV, are usually considered [subtransmission](#) voltages, but are occasionally used on long lines with light loads. Voltages less than 33 kV are usually used for [distribution](#). Voltages above 765 kV are considered [extra high voltage](#) and require different designs.

Overhead transmission wires depend on air for insulation, requiring that lines maintain minimum clearances. Adverse weather conditions, such as high winds and low temperatures, interrupt transmission. Wind speeds as low as 23 knots (43 km/h) can permit conductors to encroach operating clearances, resulting in a [flashover](#) and loss of supply.<sup>[3]</sup> Oscillatory motion of the physical line is termed [conductor gallop or flutter](#) depending on the frequency and amplitude of oscillation.



A five-hundred kilovolt (500 kV) three-phase transmission tower in Washington State, the line is bundled 3-ways



Three abreast electrical pylons in Webster, Texas

Underground

Main article: [Undergrounding](#)

Electric power can be transmitted by [underground power cables](#). Underground cables take up no right-of-way, have lower visibility, and are less affected by weather. However, cables must be insulated. Cable and excavation costs are much higher than overhead construction. Faults in buried transmission lines take longer to locate and repair.

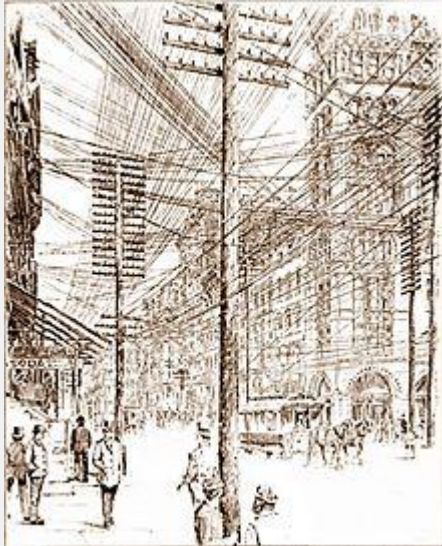
In some metropolitan areas, cables are enclosed by metal pipe and insulated with [dielectric fluid](#) (usually an oil) that is either static or circulated via pumps. If an electric fault damages the pipe and leaks dielectric, liquid nitrogen is used to freeze portions of the pipe to enable draining and repair. This extends the repair period and increases costs. The temperature of

the pipe and surroundings are monitored throughout the repair period.<sup>[4][5][6]</sup>

Underground lines are limited by their thermal capacity, which permits less overload or re-rating lines. Long underground AC cables have significant [capacitance](#), which reduces their ability to provide useful power beyond 50 miles (80 kilometres). DC cables are not limited in length by their capacitance.

## History

Main article: [History of electric power transmission](#)



New York City streets in 1890. Besides telegraph lines, multiple electric lines were required for each class of device requiring different voltages.

Commercial electric power was initially transmitted at the same voltage used by lighting and mechanical loads. This restricted the distance between generating plant and loads. In 1882, DC voltage could not easily be increased for long-distance transmission. Different classes of loads (for example, lighting, fixed motors, and traction/railway systems) required different voltages, and so used different generators and circuits.<sup>[7][8]</sup>

Thus, generators were sited near their loads, a practice that later became known as [distributed generation](#) using large numbers of small generators.<sup>[9]</sup>

Transmission of [alternating current](#) (AC) became possible after [Lucien Gaulard](#) and [John Dixon Gibbs](#) built what they called the secondary generator, an early [transformer](#) provided with 1:1 turn ratio and open magnetic circuit, in 1881.

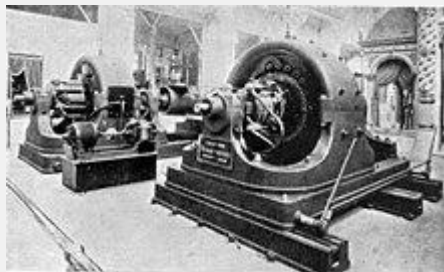
The first long distance AC line was 34 kilometres (21 miles) long, built for the 1884 International Exhibition of Electricity in [Turin, Italy](#). It was powered by a 2 kV, 130 Hz [Siemens & Halske](#) alternator and featured several Gaulard transformers with primary windings connected in series, which fed incandescent lamps. The system proved the

feasibility of AC electric power transmission over long distances.<sup>[8]</sup>

The first commercial AC distribution system entered service in 1885 in via dei Cerchi, [Rome, Italy](#), for public lighting. It was powered by two Siemens & Halske alternators rated 30 hp (22 kW), 2 kV at 120 Hz and used 19 km of cables and 200 parallel-connected 2 kV to 20 V step-down transformers provided with a closed magnetic circuit, one for each lamp. A few months later it was followed by the first British AC system, serving [Grosvenor Gallery](#). It also featured Siemens alternators and 2.4 kV to 100 V step-down transformers – one per user – with shunt-connected primaries.<sup>[10]</sup>

Working to improve what he considered an impractical Gaulard-Gibbs design, electrical engineer [William Stanley, Jr.](#) developed the first practical series AC transformer in 1885.<sup>[11]</sup> Working with the support of [George Westinghouse](#), in 1886 he demonstrated a transformer-based AC lighting system in [Great Barrington, Massachusetts](#). It was powered by a steam engine-driven 500 V Siemens generator. Voltage was stepped down to 100 volts using the Stanley transformer to power incandescent lamps at 23 businesses over 4,000 feet (1,200 m).<sup>[12]</sup> This practical demonstration of a transformer and alternating current lighting system led Westinghouse to begin installing AC systems later that year.<sup>[11]</sup>

In 1888 the first designs for an [AC motor](#) appeared. These were [induction motors](#) running on [polyphase](#) current, independently invented by [Galileo Ferraris](#) and [Nikola Tesla](#). Westinghouse licensed Tesla's design. Practical [three-phase](#) motors were designed by [Mikhail Dolivo-Dobrovolsky](#) and [Charles Eugene Lancelot Brown](#).<sup>[13]</sup> Widespread use of such motors were delayed many years by development problems and the scarcity of [polyphase power systems](#) needed to power them.<sup>[14][15]</sup>



Westinghouse alternating current [polyphase](#) generators on display at the 1893 [World's Fair in Chicago](#), part of their Tesla Poly-phase System. Such polyphase innovations revolutionized transmission.

In the late 1880s and early 1890s smaller electric companies merged into larger corporations such as [Ganz](#) and [AEG](#) in Europe and [General Electric](#) and [Westinghouse Electric](#) in the US. These companies developed AC systems, but the technical difference between direct and alternating current systems required a much longer technical merger.<sup>[16]</sup> Alternating current's economies of scale with large generating plants and long-distance transmission slowly added the ability to link all the loads. These included single phase AC systems, poly-phase AC systems, low voltage incandescent lighting, high-voltage arc lighting, and existing DC motors in factories and street cars. In what became a universal system,

these technological differences were temporarily bridged via the [rotary converters](#) and [motor-generators](#) that allowed the legacy systems to connect to the AC grid.<sup>[16][17]</sup> These stopgaps were slowly replaced as older systems were retired or upgraded.

The first transmission of single-phase alternating current using high voltage came in Oregon in 1890 when power was delivered from a hydroelectric plant at [Willamette Falls](#) to the city of [Portland](#) 14 miles (23 km) down river.<sup>[18]</sup> The first three-phase alternating current using high voltage took place in 1891 during the [international electricity exhibition](#) in [Frankfurt](#). A 15 kV transmission line, approximately 175 km long, connected [Lauffen on the Neckar](#) and Frankfurt.<sup>[10][19]</sup>

Transmission voltages increased throughout the 20th century. By 1914, fifty-five transmission systems operating at more than 70 kV were in service. The highest voltage then used was 150 kV.<sup>[20]</sup> Interconnecting multiple generating plants over a wide area reduced costs. The most efficient plants could be used to supply varying loads during the day. Reliability was improved and capital costs were reduced, because stand-by generating capacity could be shared over many more customers and a wider area. Remote and low-cost sources of energy, such as [hydroelectric](#) power or mine-mouth coal, could be exploited to further lower costs.<sup>[7][10]</sup>

The 20th century's rapid industrialization made electrical transmission lines and grids [critical infrastructure](#). Interconnection of local generation plants and small distribution networks was spurred by [World War I](#), when large electrical generating plants were built by governments to power munitions factories.<sup>[21]</sup>

Bulk transmission



A [transmission substation](#) decreases the voltage of incoming electricity, allowing it to connect from long-distance high-voltage transmission, to local lower voltage distribution. It also reroutes power to other transmission lines that serve local markets. This is the [PacifiCorp](#) Hale Substation, [Orem, Utah](#), US.

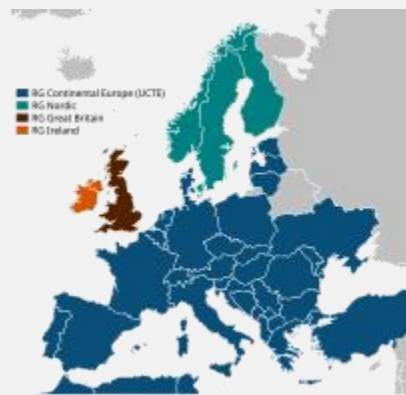
These networks use components such as power lines, cables, [circuit breakers](#), switches and [transformers](#). The transmission network is usually administered on a regional basis by an entity such as a [regional transmission organization](#) or [transmission system operator](#).<sup>[22]</sup>

Transmission efficiency is improved at higher voltage and lower current. The reduced current reduces heating losses. [Joule's first law](#) states that energy losses are proportional to the square of the current. Thus, reducing the current by a factor of two lowers the energy lost to conductor resistance by a factor of four for any given size of conductor.

The optimum size of a conductor for a given voltage and current can be estimated by Kelvin's law for conductor size, which states that size is optimal when the annual cost of energy wasted in resistance is equal to the annual capital charges of providing the conductor. At times of lower interest rates and low commodity costs, Kelvin's law indicates that thicker wires are optimal. Otherwise, thinner conductors are indicated. Since power lines are designed for long-term use, Kelvin's law is used in conjunction with long-term estimates of the price of copper and aluminum as well as interest rates.

Higher voltage is achieved in AC circuits by using a *step-up transformer*. [High-voltage direct current](#) (HVDC) systems require relatively costly conversion equipment that may be economically justified for particular projects such as submarine cables and longer distance high capacity point-to-point transmission. HVDC is necessary for sending energy between unsynchronized grids.

A transmission grid is a network of [power stations](#), transmission lines, and [substations](#). Energy is usually transmitted within a grid with [three-phase AC](#). Single-phase AC is used only for distribution to end users since it is not usable for large polyphase [induction motors](#). In the 19th century, two-phase transmission was used but required either four wires or three wires with unequal currents. Higher order phase systems require more than three wires, but deliver little or no benefit.



The [synchronous grids](#) of Europe

While the price of generating capacity is high, energy demand is variable, making it often cheaper to import needed power than to generate it locally. Because loads often rise and fall together across large areas, power often comes from distant sources. Because of the economic benefits of load sharing, [wide area transmission grids](#) may span countries and even continents. Interconnections between producers and consumers enables power to flow even if some links are inoperative.

The slowly varying portion of demand is known as the [base load](#) and is generally served by large facilities with constant operating costs, termed [firm power](#). Such facilities are nuclear, coal or hydroelectric, while other energy sources such as [concentrated solar thermal](#) and [geothermal power](#) have the potential to provide firm power. Renewable energy sources, such as solar photovoltaics, wind, wave, and tidal, are, due to their intermittency, not considered to be firm. The remaining or *peak* power demand, is supplied by [peaking power plants](#), which are typically smaller, faster-responding, and higher cost sources, such as [combined cycle](#) or combustion turbine plants typically fueled by natural gas.

Long-distance transmission (hundreds of kilometers) is cheap and efficient, with costs of US\$0.005–0.02 per kWh, compared to annual averaged large producer costs of US\$0.01–0.025 per kWh, retail rates upwards of US\$0.10 per kWh, and multiples of retail for instantaneous suppliers at unpredicted high demand moments.<sup>[23]</sup> New York often buys over 1000 MW of low-cost hydropower from Canada.<sup>[24]</sup> Local sources (even if more expensive and infrequently used) can protect the power supply from weather and other disasters that can disconnect distant suppliers.



A high-power electrical transmission tower, 230 kV, double-circuit, also double-bundled

Hydro and wind sources cannot be moved closer to big cities, and solar costs are lowest in remote areas where local power needs are nominal. Connection costs can determine whether any particular renewable alternative is economically realistic. Costs can be prohibitive for transmission lines, but high capacity, long distance [super grid](#) transmission network costs could be recovered with modest usage fees.

Grid input



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At [power stations](#), power is produced at a relatively low voltage between about 2.3 kV and 30 kV, depending on the size of the unit. The voltage is then stepped up by the power station [transformer](#) to a higher voltage (115 kV to 765 kV AC) for transmission.

In the United States, power transmission is, variously, 230 kV to 500 kV, with less than

230 kV or more than 500 kV as exceptions.

The [Western Interconnection](#) has two primary interchange voltages: 500 kV AC at 60 Hz, and  $\pm 500$  kV (1,000 kV net) DC from North to South ([Columbia River](#) to [Southern California](#)) and Northeast to Southwest (Utah to Southern California). The 287.5 kV ([Hoover Dam](#) to [Los Angeles](#) line, via [Victorville](#)) and 345 kV ([Arizona Public Service](#) (APS) line) are local standards, both of which were implemented before 500 kV became practical.

## Losses

Transmitting electricity at high voltage reduces the fraction of energy lost to [Joule heating](#), which varies by conductor type, the current, and the transmission distance. For example, a 100 miles (160 km) span at 765 kV carrying 1000 MW of power can have losses of 0.5% to 1.1%. A 345 kV line carrying the same load across the same distance has losses of 4.2%.<sup>[25]</sup> For a given amount of power, a higher voltage reduces the current and thus the [resistive losses](#). For example, raising the voltage by a factor of 10 reduces the current by a

corresponding factor of 10 and therefore the losses by a factor of 100, provided the same sized conductors are used in both cases. Even if the conductor size (cross-sectional area) is decreased ten-fold to match the lower current, the losses are still reduced ten-fold using the higher voltage.

While power loss can also be reduced by increasing the wire's [conductance](#) (by increasing its cross-sectional area), larger conductors are heavier and more expensive. And since conductance is proportional to cross-sectional area, resistive power loss is only reduced proportionally with increasing cross-sectional area, providing a much smaller benefit than the squared reduction provided by multiplying the voltage.

Long-distance transmission is typically done with overhead lines at voltages of 115 to 1,200 kV. At higher voltages, where more than 2,000 kV exists between conductor and ground, [corona discharge](#) losses are so large that they can offset the lower resistive losses in the line conductors. Measures to reduce corona losses include larger conductor diameter, hollow cores<sup>[26]</sup> or conductor bundles.

Factors that affect resistance and thus loss include temperature, spiraling, and the [skin effect](#). Resistance increases with temperature. Spiraling, which refers to the way stranded conductors spiral about the center, also contributes to increases in conductor resistance. The skin effect causes the effective resistance to increase at higher AC frequencies. Corona and resistive losses can be estimated using a mathematical model.<sup>[27]</sup>

US transmission and distribution losses were estimated at 6.6% in 1997,<sup>[28]</sup> 6.5% in 2007<sup>[28]</sup> and 5% from 2013 to 2019.<sup>[29]</sup> In general, losses are estimated from the discrepancy between power produced (as reported by power plants) and power sold; the difference

constitutes transmission and distribution losses, assuming no utility theft occurs.

As of 1980, the longest cost-effective distance for DC transmission was 7,000 kilometres (4,300 miles). For AC it was 4,000 kilometres (2,500 miles), though US transmission lines are substantially shorter.<sup>[23]</sup>

In any AC line, conductor [inductance](#) and [capacitance](#) can be significant. Currents that flow solely in reaction to these properties, (which together with the [resistance](#) define the [impedance](#)) constitute [reactive power](#) flow, which transmits no power to the load. These reactive currents, however, cause extra heating losses. The ratio of real power transmitted to the load to apparent power (the product of a circuit's voltage and current, without reference to phase angle) is the [power factor](#). As reactive current increases, reactive power increases and power factor decreases.

For transmission systems with low power factor, losses are higher than for systems with high power factor. Utilities add capacitor banks, reactors and other components (such as [phase-shifters](#); [static VAR compensators](#); and [flexible AC transmission systems](#), FACTS) throughout the system help to compensate for the reactive power flow, reduce the losses in power transmission and stabilize system voltages. These measures are collectively called 'reactive support'.

Transposition



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Current flowing through transmission lines induces a [magnetic field](#) that surrounds the lines of each phase and affects the [inductance](#) of the surrounding conductors of other phases. The conductors' mutual inductance is partially dependent on the physical orientation of the lines with respect to each other. Three-phase lines are conventionally strung with phases separated vertically. The mutual inductance seen by a conductor of the phase in the middle of the other two phases is different from the inductance seen on the top/bottom.

Unbalanced inductance among the three conductors is problematic because it may force the middle line to carry a disproportionate amount of the total power transmitted. Similarly, an unbalanced load may occur if one line is consistently closest to the ground and operates at a lower impedance. Because of this phenomenon, conductors must be periodically transposed along the line so that each phase sees equal time in each relative position to balance out the mutual inductance seen by all three phases. To accomplish this, line position is swapped at specially designed [transposition towers](#) at regular intervals along the line using various [transposition schemes](#).

## Subtransmission



A 115 kV subtransmission line in the [Philippines](#), along with 20 kV [distribution](#) lines and a [street light](#), all mounted on a wood [subtransmission pole](#)



115 kV H-frame transmission tower



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Subtransmission runs at relatively lower voltages. It is uneconomical to connect all [distribution substations](#) to the high main transmission voltage, because that equipment is larger and more expensive. Typically, only larger substations connect with this high voltage. Voltage is stepped down before the current is sent to smaller substations. Subtransmission circuits are usually arranged in loops so that a single line failure does not stop service to many customers for more than a short time.

Loops can be *normally closed*, where loss of one circuit should result in no interruption, or *normally open* where substations can switch to a backup supply. While subtransmission circuits are usually carried on [overhead lines](#), in urban areas buried cable may be used. The lower-voltage subtransmission lines use less right-of-way and simpler structures;

undergrounding is less difficult.

No fixed cutoff separates subtransmission and transmission, or subtransmission and [distribution](#). Their voltage ranges overlap. Voltages of 69 kV, 115 kV, and 138 kV are often used for subtransmission in North America. As power systems evolved, voltages formerly used for transmission were used for subtransmission, and subtransmission voltages became distribution voltages. Like transmission, subtransmission moves relatively large amounts of power, and like distribution, subtransmission covers an area instead of just point-to-point.<sup>[30]</sup>

Transmission grid exit

[Substation](#) transformers reduce the voltage to a lower level for [distribution](#) to customers. This distribution is accomplished with a combination of sub-transmission (33 to 138 kV) and distribution (3.3 to 25 kV). Finally, at the point of use, the energy is transformed to end-user voltage (100 to 4160 volts).

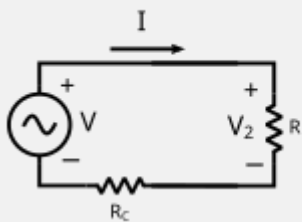
Advantage of high-voltage transmission

See also: [Ideal transformer](#)

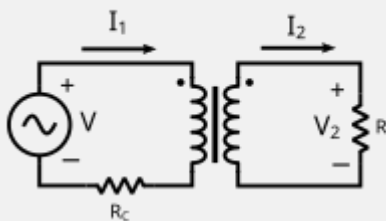


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High-voltage power transmission allows for lesser resistive losses over long distances. This efficiency delivers a larger proportion of the generated power to the loads.



Electrical grid without a transformer



Electrical grid with a transformer

In a simplified model, the grid delivers electricity from an [ideal voltage source](#) with voltage

, delivering a power ) to a single point of consumption, modelled by a resistance , when the wires are long enough to have a significant resistance .

If the resistances are [in series](#) with no intervening transformer, the circuit acts as a [voltage divider](#), because the same current runs through the wire resistance and the powered device. As a consequence, the useful power (at the point of consumption) is:

Should an [ideal transformer](#) convert high-voltage, low-current electricity into low-voltage, high-current electricity with a voltage ratio of (i.e., the voltage is divided by and the current is multiplied by in the secondary branch, compared to the primary branch), then the circuit is again equivalent to a voltage divider, but the wires now have apparent resistance of only . The useful power is then:

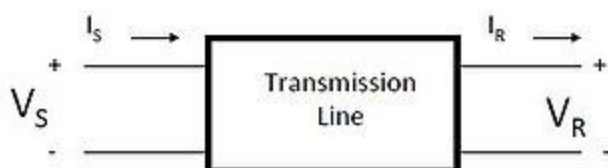
For (i.e. conversion of high voltage to low voltage near the consumption point), a larger fraction of the generator's power is transmitted to the consumption point and a lesser fraction is lost to [Joule heating](#).

Modeling

Main article: [Performance and modelling of AC transmission](#)



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"Black box" model for transmission

line

The terminal characteristics of the transmission line are the voltage and current at the sending (S) and receiving (R) ends. The transmission line can be modeled as a [black box](#) and

a 2 by 2 transmission matrix is used to model its behavior, as follows:

The line is assumed to be a reciprocal, symmetrical network, meaning that the receiving and sending labels can be switched with no consequence. The transmission matrix  $T$  has the properties:

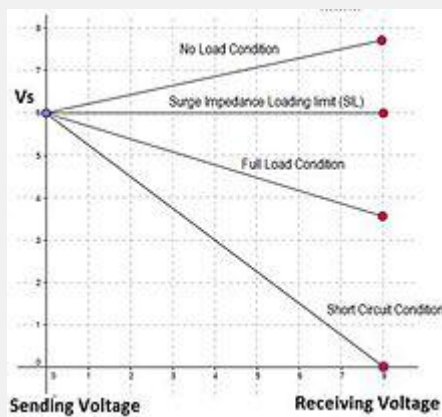
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The parameters  $A$ ,  $B$ ,  $C$ , and  $D$  differ depending on how the desired model handles the line's [resistance](#) ( $R$ ), [inductance](#) ( $L$ ), [capacitance](#) ( $C$ ), and shunt (parallel, leak) [conductance](#)  $G$ .

The four main models are the short line approximation, the medium line approximation, the long line approximation (with distributed parameters), and the lossless line. In such models, a capital letter such as  $R$  refers to the total quantity summed over the line and a lowercase letter such as  $c$  refers to the per-unit-length quantity.

#### Lossless line

The lossless line approximation is the least accurate; it is typically used on short lines where the inductance is much greater than the resistance. For this approximation, the voltage and current are identical at the sending and receiving ends.



Voltage on sending and receiving ends for lossless line

The characteristic impedance is pure real, which means resistive for that impedance, and it is often called surge impedance. When a lossless line is terminated by surge impedance, the voltage does not drop. Though the phase angles of voltage and current are rotated, the magnitudes of voltage and current remain constant along the line. For load  $>$  SIL, the voltage drops from sending end and the line *consumes* VARs. For load  $<$  SIL, the voltage

increases from the sending end, and the line *generates* VARs.

#### Short line

The short line approximation is normally used for lines shorter than 80 km (50 mi). There, only a series impedance  $Z$  is considered, while  $C$  and  $G$  are ignored. The final result is that  $A = D = 1$  per unit,  $B = Z$  Ohms, and  $C = 0$ . The associated transition matrix for this approximation is therefore:

#### Medium line

The medium line approximation is used for lines running between 80 and 250 km (50 and 155 mi). The series impedance and the shunt (current leak) conductance are considered, placing half of the shunt conductance at each end of the line. This circuit is often referred to as a *nominal  $\pi$  (pi)* circuit because of the shape ( $\pi$ ) that is taken on when leak conductance is placed on both sides of the circuit diagram. The analysis of the medium line produces:

Counterintuitive behaviors of medium-length transmission lines:

- voltage rise at no load or small current ([Ferranti effect](#))
- receiving-end current can exceed sending-end current

#### Long line

The long line model is used when a higher degree of accuracy is needed or when the line under consideration is more than 250 km (160 mi) long. Series resistance and shunt conductance are considered to be distributed parameters, such that each differential length of the line has a corresponding differential series impedance and shunt admittance. The

following result can be applied at any point along the transmission line, where  $\gamma$  is the [propagation constant](#).

To find the voltage and current at the end of the long line,  $l$  should be replaced with  $\gamma l$  (the line length) in all parameters of the transmission matrix. This model applies the

## [Telegrapher's equations.](#)

High-voltage direct current

Main article: [High-voltage direct current](#)

High-voltage direct current (HVDC) is used to transmit large amounts of power over long distances or for interconnections between asynchronous grids. When electrical energy is transmitted over very long distances, the power lost in AC transmission becomes appreciable and it is less expensive to use direct current instead. For a long transmission line, these lower losses (and reduced construction cost of a DC line) can offset the cost of the required converter stations at each end.

HVDC is used for long [submarine cables](#) where AC cannot be used because of cable capacitance.<sup>[31]</sup> In these cases special [high-voltage cables](#) are used. Submarine HVDC systems are often used to interconnect the electricity grids of islands, for example, between [Great Britain](#) and [continental Europe](#), between Great Britain and Ireland, between [Tasmania](#) and the Australian mainland, between the North and South Islands of New Zealand, between [New Jersey](#) and [New York City](#), and between New Jersey and [Long Island](#). Submarine connections up to 600 kilometres (370 mi) in length have been deployed.<sup>[32]</sup>

HVDC links can be used to control grid problems. The power transmitted by an AC line increases as the [phase angle](#) between source end voltage and destination ends increases, but too large a phase angle allows the systems at either end to fall out of step. Since the power flow in a DC link is controlled independently of the phases of the AC networks that it connects, this phase angle limit does not exist, and a DC link is always able to transfer its full rated power. A DC link therefore stabilizes the AC grid at either end, since power flow and phase angle can then be controlled independently.

As an example, to adjust the flow of AC power on a hypothetical line between [Seattle](#) and [Boston](#) would require adjustment of the relative phase of the two regional electrical grids. This is an everyday occurrence in AC systems, but one that can become disrupted when AC system components fail and place unexpected loads on the grid. With an HVDC line instead, such an interconnection would:

- Convert AC in Seattle into HVDC;
- Use HVDC for the 3,000 miles (4,800 km) of cross-country transmission; and
- Convert the HVDC to locally synchronized AC in Boston,

(and possibly in other cooperating cities along the transmission route). Such a system could be less prone to failure if parts of it were suddenly shut down. One example of a long DC transmission line is the [Pacific DC Intertie](#) located in the Western United States.

## Capacity



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The amount of power that can be sent over a transmission line varies with the length of the line. The heating of short line conductors due to line losses sets a thermal limit. If too much current is drawn, conductors may sag too close to the ground, or conductors and equipment may overheat. For intermediate-length lines on the order of 100 kilometres (62 miles), the limit is set by the [voltage drop](#) in the line. For longer AC lines, [system stability](#) becomes the limiting factor. Approximately, the power flowing over an AC line is proportional to the cosine of the phase angle of the voltage and current at the ends.

This angle varies depending on system loading. It is undesirable for the angle to approach 90 degrees, as the power flowing decreases while resistive losses remain. The product of line length and maximum load is approximately proportional to the square of the system voltage. Series capacitors or phase-shifting transformers are used on long lines to improve stability. HVDC lines are restricted only by thermal and voltage drop limits, since the phase angle is not material.

Understanding the temperature distribution along the cable route became possible with the introduction of [distributed temperature sensing](#) (DTS) systems that measure temperatures all along the cable. Without them maximum current was typically set as a compromise between understanding of operation conditions and risk minimization. This monitoring solution uses passive [optical fibers](#) as temperature sensors, either inside a high-voltage cable or externally mounted on the cable insulation.

For overhead cables the fiber is integrated into the core of a phase wire. The integrated Dynamic Cable Rating (DCR)/Real Time Thermal Rating (RTTR) solution makes it possible to run the network to its maximum. It allows the operator to predict the behavior of the transmission system to reflect major changes to its initial operating conditions.

## Reconductoring

Some utilities have embraced reconductoring to handle the increase in electricity production. Reconductoring is the replacement-in-place of existing transmission lines with higher-capacity lines. Adding transmission lines is difficult due to cost, permit intervals, and local opposition. Reconductoring has the potential to double the amount of electricity that can travel across a transmission line.<sup>[33]</sup> A 2024 report found the United States behind countries like Belgium and the Netherlands in adoption of this technique to accommodate electrification and renewable energy.<sup>[34]</sup> In April 2022, the [Biden Administration](#) streamlined environmental reviews for such projects, and in May 2022 announced competitive grants for them funded by the 2021 [Bipartisan Infrastructure Law](#) and 2022

## [Inflation Reduction Act.](#)<sup>[35]</sup>

The rate of transmission expansion needs to double to support ongoing electrification and reach emission reduction targets. As of 2022, more than 10,000 power plant and energy storage projects were awaiting permission to connect to the US grid — 95% were zero-carbon resources. New power lines can take 10 years to plan, permit, and build.<sup>[33]</sup>

Traditional power lines use a steel core surrounded by aluminum strands ([Aluminium-conductor steel-reinforced cable](#)). Replacing the steel with a lighter, stronger composite material such as [carbon fiber](#) ([ACCC conductor](#)) allows lines to operate at higher temperatures, with less sag, and doubled transmission capacity. Lowering line sag at high temperatures can prevent wildfires from starting when power lines touch dry vegetation.<sup>[34]</sup> Although advanced lines can cost 2-4x more than steel, total reconductoring costs are less than half of a new line, given savings in time, land acquisition, permitting, and construction.<sup>[33]</sup>

A reconductoring project in southeastern Texas upgraded 240 miles of transmission lines at a cost of \$900,000 per mile, versus a 3,600-mile greenfield project that averaged \$1.9 million per mile.<sup>[33]</sup>

Control



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To ensure safe and predictable operation, system components are controlled with generators, switches, circuit breakers and loads. The voltage, power, frequency, load factor, and reliability capabilities of the transmission system are designed to provide cost effective performance.

Load balancing

The transmission system provides for base load and [peak load capability](#), with margins for safety and fault tolerance. Peak load times vary by region largely due to the industry mix. In hot and cold climates home air conditioning and heating loads affect the overall load. They are typically highest in the late afternoon in the hottest part of the year and in mid-mornings and mid-evenings in the coldest part of the year. Power requirements vary by season and time of day. Distribution system designs always take the base load and the peak load into consideration.

The transmission system usually does not have a large buffering capability to match loads with generation. Thus generation has to be kept matched to the load, to prevent

overloading generation equipment.

Multiple sources and loads can be connected to the transmission system and they must be controlled to provide orderly transfer of power. In centralized power generation, only local control of generation is necessary. This involves [synchronization of the generation units](#).

In [distributed power generation](#) the generators are geographically distributed and the process to bring them online and offline must be carefully controlled. The load control signals can either be sent on separate lines or on the power lines themselves. Voltage and frequency can be used as signaling mechanisms to balance the loads.

In voltage signaling, voltage is varied to increase generation. The power added by any system increases as the line voltage decreases. This arrangement is stable in principle. Voltage-based regulation is complex to use in mesh networks, since the individual components and setpoints would need to be reconfigured every time a new generator is added to the mesh.

In frequency signaling, the generating units match the frequency of the power transmission system. In [droop speed control](#), if the frequency decreases, the power is increased. (The drop in line frequency is an indication that the increased load is causing the generators to slow down.)

[Wind turbines](#), [vehicle-to-grid](#), [virtual power plants](#), and other locally distributed storage and generation systems can interact with the grid to improve system operation. Internationally<sup>[[where?](#)]</sup>, a slow move from a centralized to decentralized power systems have taken place. The main draw of locally distributed generation systems is that they reduce transmission losses by leading to consumption of electricity closer to where it was produced.<sup>[36]</sup>

Failure protection

Under excess load conditions, the system can be designed to fail incrementally rather than all at once. [Brownouts](#) occur when power supplied drops below the demand. [Blackouts](#) occur when the grid fails completely.

[Rolling blackouts](#) (also called load shedding) are intentionally engineered electrical power outages, used to distribute insufficient power to various loads in turn.

Communications



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Grid operators require reliable communications to manage the grid and associated generation and distribution facilities. Fault-sensing [protective relays](#) at each end of the line must communicate to monitor the flow of power so that faulted conductors or equipment can be quickly de-energized and the balance of the system restored. Protection of the transmission line from [short circuits](#) and other faults is usually so critical that [common carrier](#) telecommunications are insufficiently reliable, while in some remote areas no common carrier is available. Communication systems associated with a transmission project may use:

- [Microwaves](#)
- [Power-line communication](#)
- [Optical fibers](#)

Rarely, and for short distances, pilot-wires are strung along the transmission line path. Leased circuits from common carriers are not preferred since availability is not under control of the operator.

Transmission lines can be used to carry data: this is called power-line carrier, or [power-line communication](#) (PLC). PLC signals can be easily received with a radio in the long wave range.



High-voltage pylons carrying additional optical fibre cable in Kenya

Optical fibers can be included in the stranded conductors of a transmission line, in the overhead shield wires. These cables are known as [optical ground wire](#) (OPGW). Sometimes a standalone cable is used, all-dielectric self-supporting (ADSS) cable, attached to the transmission line cross arms.

Some jurisdictions, such as [Minnesota](#), prohibit energy transmission companies from selling

surplus communication bandwidth or acting as a telecommunications [common carrier](#). Where the regulatory structure permits, the utility can sell capacity in extra [dark fibers](#) to a common carrier.

Market structure

Main article: [Electricity market](#)

Electricity transmission is generally considered to be a [natural monopoly](#), but one that is not inherently linked to generation.<sup>[37][38][39]</sup> Many countries regulate transmission separately from generation.

Spain was the first country to establish a [regional transmission organization](#). In that country, transmission operations and electricity markets are separate. The transmission system operator is [Red Eléctrica de España](#) (REE) and the wholesale electricity market operator is Operador del Mercado Ibérico de Energía – Polo Español, S.A. (OMEL) [OMEL Holding | Omel Holding](#). Spain's transmission system is interconnected with those of France, Portugal, and Morocco.

The establishment of RTOs in the United States was spurred by the [FERC's Order 888, Promoting Wholesale Competition Through Open Access Non-discriminatory Transmission Services by Public Utilities; Recovery of Stranded Costs by Public Utilities and Transmitting Utilities](#), issued in 1996.<sup>[40]</sup> In the United States and parts of Canada, electric transmission companies operate independently of generation companies, but in the Southern United States vertical integration is intact. In regions of separation, transmission owners and generation owners continue to interact with each other as market participants with voting rights within their RTO. RTOs in the United States are regulated by the [Federal Energy Regulatory Commission](#).

Merchant transmission projects in the United States include the [Cross Sound Cable](#) from [Shoreham, New York](#) to [New Haven, Connecticut](#), Neptune RTS Transmission Line from [Sayreville, New Jersey](#), to [New Bridge, New York](#), and [Path 15](#) in California. Additional projects are in development or have been proposed throughout the United States, including the [Lake Erie Connector](#), an underwater transmission line proposed by ITC Holdings Corp., connecting Ontario to [load serving entities](#) in the PJM Interconnection region.<sup>[41]</sup>

Australia has one unregulated or market interconnector – [Basslink](#) – between [Tasmania](#) and [Victoria](#). Two DC links originally implemented as market interconnectors, [Directlink](#) and [Murraylink](#), were converted to regulated interconnectors.<sup>[42]</sup>

A major barrier to wider adoption of merchant transmission is the difficulty in identifying who benefits from the facility so that the beneficiaries pay the toll. Also, it is difficult for a merchant transmission line to compete when the alternative transmission lines are subsidized by utilities with a monopolized and regulated rate base.<sup>[43]</sup> In the United States,

the [FERC's Order 1000](#), issued in 2010, attempted to reduce barriers to third party investment and creation of merchant transmission lines where a public policy need is found.<sup>[44]</sup>

#### Transmission costs

The cost of high voltage transmission is comparatively low, compared to all other costs constituting consumer electricity bills. In the UK, transmission costs are about 0.2 p per kWh compared to a delivered domestic price of around 10 p per kWh.<sup>[45]</sup>

The level of capital expenditure in the electric power T&D equipment market was estimated to be \$128.9 bn in 2011.<sup>[46]</sup>

#### Health concerns

Main article: [Electromagnetic radiation and health](#)

Mainstream scientific evidence suggests that low-power, low-frequency, electromagnetic radiation associated with household currents and high transmission power lines does not constitute a short- or long-term health hazard.

Some studies failed to find any link between living near power lines and developing any sickness or diseases, such as cancer. A 1997 study reported no increased risk of cancer or illness from living near a transmission line.<sup>[47]</sup> Other studies, however, reported [statistical correlations](#) between various diseases and living or working near power lines. No adverse health effects have been substantiated for people not living close to power lines.<sup>[48]</sup>

The [New York State Public Service Commission](#) conducted a study<sup>[49]</sup> to evaluate potential health effects of electric fields. The study measured the electric field strength at the edge of an existing right-of-way on a 765 kV transmission line. The field strength was 1.6 kV/m, and became the interim maximum strength standard for new transmission lines in New York State. The opinion also limited the voltage of new transmission lines built in New York to 345 kV. On September 11, 1990, after a similar study of magnetic field strengths, the NYSPSC issued their *Interim Policy Statement on Magnetic Fields*. This policy established a magnetic field standard of 200 mG at the edge of the right-of-way using the winter-normal conductor rating. As a comparison with everyday items, a hair dryer or electric blanket produces a 100 mG – 500 mG magnetic field.<sup>[50][51]</sup>

Applications for a new transmission line typically include an analysis of electric and magnetic field levels at the edge of rights-of-way. [Public utility commissions](#) typically do not comment on health impacts.

Biological effects have been established for [acute](#) high level exposure to magnetic fields above 100  $\mu\text{T}$  (1  $\text{G}$ ) (1,000 mG). In a residential setting, one study reported "limited

evidence of [carcinogenicity](#) in humans and less than sufficient evidence for carcinogenicity in experimental animals", in particular, childhood leukemia, associated with average exposure to residential power-frequency magnetic field above 0.3  $\mu\text{T}$  (3 mG) to 0.4  $\mu\text{T}$  (4 mG). These levels exceed average residential power-frequency magnetic fields in homes, which are about 0.07  $\mu\text{T}$  (0.7 mG) in Europe and 0.11  $\mu\text{T}$  (1.1 mG) in North America.<sup>[52][53]</sup>

The Earth's natural geomagnetic field strength varies over the surface of the planet between 0.035 mT and 0.07 mT (35  $\mu\text{T}$  – 70  $\mu\text{T}$  or 350 mG – 700 mG) while the international standard for continuous exposure is set at 40 mT (400,000 mG or 400 G) for the general public.<sup>[52]</sup>

Tree growth regulators and herbicides may be used in transmission line right of ways,<sup>[54]</sup> which may have [health effects](#).

Specialized transmission

Grids for railways

Main article: [Traction power network](#)

In some countries where [electric locomotives](#) or [electric multiple units](#) run on low frequency AC power, separate single phase [traction power networks](#) are operated by the railways. Prime examples are countries such as Austria, Germany and Switzerland that utilize AC technology based on 16  $\frac{2}{3}$  Hz. Norway and Sweden also use this frequency but use conversion from the 50 Hz public supply; Sweden has a 16  $\frac{2}{3}$  Hz traction grid but only for part of the system.

Superconducting cables

[High-temperature superconductors](#) (HTS) promise to revolutionize power distribution by providing lossless transmission. The development of superconductors with transition temperatures higher than the boiling point of [liquid nitrogen](#) has made the concept of superconducting power lines commercially feasible, at least for high-load applications.<sup>[55]</sup> It has been estimated that waste would be halved using this method, since the necessary refrigeration equipment would consume about half the power saved by the elimination of resistive losses. Companies such as [Consolidated Edison](#) and [American Superconductor](#) began commercial production of such systems in 2007.<sup>[56]</sup>

Superconducting cables are particularly suited to high load density areas such as the business district of large cities, where purchase of an [easement](#) for cables is costly.<sup>[57]</sup>

HTS transmission lines <sup>[58]</sup>				
Location	Length (km)	Voltage (kV)	Capacity (GW)	Date
Carrollton, Georgia				2000

Albany, New York <sup>[59]</sup>	0.35	34.5	0.048	2006
<a href="#">Holbrook, Long Island</a> <sup>[60]</sup>	0.6	138	0.574	2008
<a href="#">Tres Amigas</a>			5	Proposed 2013
Manhattan: Project Hydra				Proposed 2014
Essen, Germany <sup>[61][62]</sup>	1	10	0.04	2014

Single-wire earth return

Main article: [Single-wire earth return](#)



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Single-wire earth return (SWER) or single-wire ground return is a single-wire transmission line for supplying single-phase electrical power to remote areas at low cost. It is principally used for [rural electrification](#), but also finds use for larger isolated loads such as water pumps. Single-wire earth return is also used for HVDC over submarine power cables.

Wireless power transmission

Main article: [Wireless power transfer](#)



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Both [Nikola Tesla](#) and [Hidetsugu Yagi](#) attempted to devise systems for large scale wireless power transmission in the late 1800s and early 1900s, without commercial success.

In November 2009, LaserMotive won the NASA 2009 Power Beaming Challenge by powering a cable climber 1 km vertically using a ground-based laser transmitter. The system produced up to 1 kW of power at the receiver end. In August 2010, NASA contracted with private companies to pursue the design of laser power beaming systems to power low earth orbit satellites and to launch rockets using laser power beams.

Wireless power transmission has been studied for transmission of power from [solar power satellites](#) to the earth. A high power array of [microwave](#) or laser transmitters would beam power to a [rectenna](#). Major engineering and economic challenges face any solar power satellite project.

Security



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[create a new article](#), as appropriate. (March 2013) ([Learn how and when to remove this message](#))

The [federal government of the United States](#) stated that the American power grid was susceptible to [cyber-warfare](#).<sup>[63][64]</sup> The [United States Department of Homeland Security](#) works with industry to identify vulnerabilities and to help industry enhance the security of control system networks.<sup>[65]</sup>

In June 2019, Russia conceded that it was "possible" its [electrical grid](#) is under cyber-attack by the [United States](#).<sup>[66]</sup> *The New York Times* reported that American hackers from the [United States Cyber Command](#) planted malware potentially capable of disrupting the Russian electrical grid.<sup>[67]</sup>

## Records

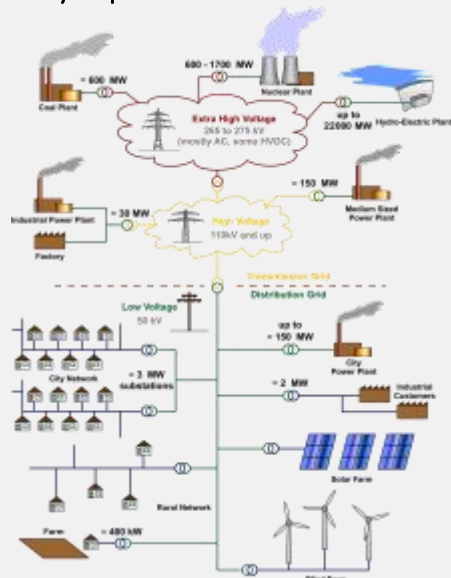
- Highest capacity system: [12 GW Zhundong–Wannan](#) ([准东-皖南](#))±1100 kV HVDC.<sup>[68][69]</sup>
- Highest transmission voltage (AC):
  - planned: 1.20 MV (Ultra-High Voltage) on Wardha-Aurangabad line (India), planned to initially operate at 400 kV.<sup>[70]</sup>
  - worldwide: 1.15 MV (Ultra-High Voltage) on [Ekibastuz-Kokshetau line](#) ([Kazakhstan](#))
- Largest double-circuit transmission, [Kita-Iwaki Powerline](#) (Japan).
- Highest [towers](#): [Yangtze River Crossing](#) (China) (height: 345 m or 1,132 ft)
- Longest power line: [Inga-Shaba](#) ([Democratic Republic of Congo](#)) (length: 1,700 kilometres or 1,056 miles)
- Longest span of power line: 5,376 m (17,638 ft) at [Ameralik Span](#) ([Greenland](#), Denmark)
- Longest submarine cables:
  - [North Sea Link](#), (Norway/United Kingdom) – (length of submarine cable: 720 kilometres or 447 miles)
  - [NorNed](#), [North Sea](#) (Norway/Netherlands) – (length of submarine cable: 580 kilometres or 360 miles)
  - [Basslink](#), [Bass Strait](#), (Australia) – (length of submarine cable: 290 kilometres or 180 miles, total length: 370.1 kilometres or 230 miles)
  - [Baltic Cable](#), [Baltic Sea](#) (Germany/Sweden) – (length of submarine cable: 238 kilometres or 148 miles, [HVDC](#) length: 250 kilometres or 155 miles, total length: 262 kilometres or 163 miles)
- Longest underground cables:
  - [Murraylink](#), [Riverland](#)/[Sunraysia](#) (Australia) – (length of underground cable: 170 kilometres or 106 miles)

See also

-  [Energy portal](#)
- [Dynamic demand \(electric power\)](#)
- [Demand response](#)
- [List of energy storage power plants](#)
- [Traction power network](#)
- [Backfeeding](#)
- [Conductor marking lights](#)
- [Double-circuit transmission line](#)
- [Electromagnetic Transients Program](#) (EMTP)
- [Flexible AC transmission system](#) (FACTS)
- [Geomagnetically induced current](#), (GIC)
- [Graphene-clad wire](#)
- [Grid-tied electrical system](#)
- [List of high-voltage underground and submarine cables](#)
- [Load profile](#)
- [National Grid](#) (disambiguation)
- [Power-line communications](#) (PLC)
- [Power system simulation](#)
- [Radio frequency power transmission](#)
- [Wheeling \(electric power transmission\)](#)

## References

## encyclopedia



An electrical grid may have many types of generators and loads; generators must be controlled to maintain stable operation of the system.

In an [electric power system](#), automatic generation control (AGC) is a system for adjusting

the power output of multiple generators at different [power plants](#), in response to changes in the load. Since a power grid requires that generation and load closely balance moment by moment, frequent adjustments to the output of generators are necessary. The balance can be judged by measuring the [system frequency](#); if it is increasing, more power is being generated than used, which causes all the machines in the system to accelerate. If the system frequency is decreasing, more load is on the system than the instantaneous generation can provide, which causes all generators to slow down.

## History

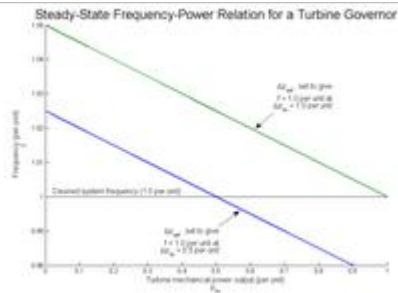
Before the use of automatic generation control, one generating unit in a system would be designated as the regulating unit and would be manually adjusted to control the balance between generation and load to maintain system frequency at the desired value. The remaining units would be controlled with [speed droop](#) to share the load in proportion to their ratings. With automatic systems, many units in a system can participate in regulation, reducing wear on a single unit's controls and improving overall system efficiency, stability, and economy.

Where the grid has tie interconnections to adjacent control areas, automatic generation control helps maintain the power interchanges over the tie lines at the scheduled levels. With computer-based control systems and multiple inputs, an automatic generation control system can take into account such matters as the most economical units to adjust, the coordination of thermal, hydroelectric, and other generation types, and even constraints related to the stability of the system and capacity of interconnections to other power grids.<sup>[1]</sup>

## Types

### Turbine-governor control

Turbine generators in a power system have stored kinetic energy due to their large rotating masses. All the kinetic energy stored in a power system in such rotating masses is a part of the grid inertia. When system load increases, grid inertia is initially used to supply the load. This, however, leads to a decrease in the stored kinetic energy of the turbine generators. Since the mechanical power of these turbines correlates with the delivered electrical power, the turbine generators have a decrease in angular velocity, which is directly proportional to a decrease in frequency in synchronous generators.



Steady state frequency-power relation for a turbine

governor

The purpose of the turbine-governor control (TGC) is to maintain the desired system frequency by adjusting the mechanical power output of the turbine.<sup>[2]</sup> These controllers have become automated and at steady state, the frequency-power relation for turbine-governor control is,

where,

is the change in turbine mechanical power output

is the change in a reference power setting

is the regulation constant which quantifies the sensitivity of the generator to a change in frequency

is the change in frequency.

For steam turbines, [steam turbine governing](#) adjusts the mechanical output of the turbine by increasing or decreasing the amount of steam entering the turbine via a throttle valve.

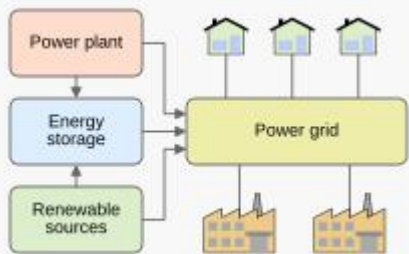
Load-frequency control

[Load-frequency control](#) (LFC) is employed to allow an area to first meet its own load demands, then to assist in returning the steady-state frequency of the system,  $\Delta f$ , to zero.<sup>[3]</sup> Load-frequency control operates with a response time of a few seconds to keep system frequency stable.

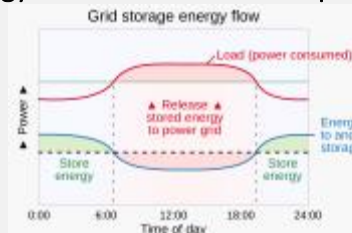
Economic dispatch

The goal of [economic dispatch](#) is to minimize total operating costs in an area by determining how the real power output of each generating unit will meet a given load.<sup>[4]</sup> Generating units have different costs to produce a unit of electrical energy, and incur different costs for the losses in transmitting energy to the load. An economic dispatch algorithm will run every few minutes to select the combination of generating unit power setpoints that minimizes overall cost, subject to the constraints of transmission limitation or security of the system against failures.<sup>[5]</sup> Further constraints may be imposed by the water supply of [hydroelectric](#) generation, or by the availability of sun and wind power.

"Grid storage" redirects here. For data storage with grid computing, see [Grid-oriented storage](#).



Energy from fossil or nuclear power plants and renewable



sources is stored for use by customers.

Diagram showing flow of energy between energy storage facilities and power grids, as a function of time over a 24 hour period

Grid energy storage, also known as large-scale energy storage, are technologies connected to the [electrical power grid](#) that [store energy](#) for later use. These systems help balance supply and demand by storing excess electricity from [variable renewables](#) such as [solar](#) and inflexible sources like [nuclear power](#), releasing it when needed. They further provide [essential grid services](#), such as helping to [restart the grid](#) after a [power outage](#).

As of 2023, the largest form of grid storage is [pumped-storage hydroelectricity](#), with [utility-scale batteries](#) and behind-the-meter batteries coming second and third.<sup>[1]</sup> [Lithium-ion batteries](#) are highly suited for shorter duration storage up to 8 hours. [Flow batteries](#) and [compressed air energy storage](#) may provide storage for medium duration. Two forms of storage are suited for long-duration storage: [green hydrogen](#), produced via [electrolysis](#) and [thermal energy storage](#).<sup>[2]</sup>

Energy storage is one option to making grids more flexible. An other solution is the use of more [dispatchable power plants](#) that can change their output rapidly, for instance [peaking power plants](#) to fill in supply gaps. [Demand response](#) can shift load to other times and

[interconnections](#) between regions can balance out fluctuations in renewables production.<sup>[3]</sup>

The price of storage technologies typically [goes down with experience](#). For instance, lithium-ion batteries have been getting some 20% cheaper for each doubling of worldwide capacity.<sup>[4]</sup> Systems with under 40% variable renewables need only short-term storage. At 80%, medium-duration storage becomes essential and beyond 90%, long-duration storage does too. The economics of long-duration storage is challenging, and alternative flexibility options like demand response may be more economic.

#### Roles in the power grid

Any [electrical power grid](#) must match electricity production to consumption, both of which vary significantly over time. Energy derived from [solar](#) and [wind sources](#) varies with the weather on time scales ranging from less than a second to weeks or longer. [Nuclear power](#) is less flexible than [fossil fuels](#), meaning it cannot easily match the variations in demand. Thus, [low-carbon electricity](#) without storage presents special challenges to [electric utilities](#).<sup>[5]</sup>

Electricity storage is one of the three key ways to replace flexibility from [fossil fuels](#) in the grid. Other options are [demand-side response](#), in which consumers change when they use electricity or how much they use. For instance, households may have [cheaper night tariffs](#) to encourage them to use electricity at night. Industry and commercial consumers can also change their demand to meet supply. Improved [network interconnection](#) smooths the variations of renewables production and demand. When there is little wind in one location, another might have a surplus of production. Expansion of [transmission lines](#) usually takes a long time.<sup>[6]</sup>

Potential roles of energy storage in the grid <sup>[7][8]</sup>			
	Consumption	Network	Generation
Short-term flexibility	Increased use <a href="#">rooftop solar</a> , cost reductions from <a href="#">time-based</a> rates	<a href="#">Congestion</a> relief	Renewables integration (smoothing, <a href="#">arbitrage</a> )
Essential grid services	Backup power during outages	<a href="#">Frequency regulation</a>	<a href="#">Black start</a>
System reliability and planning	Creation of <a href="#">mini-grids</a>	Savings in transmission and <a href="#">distribution network</a>	Meeting <a href="#">peak demand</a>

Energy storage has a large set of roles in the electricity grid and can therefore provide many different services. For instance, it can [arbitrage](#) by keeping it until the [electricity price](#) rises, it can help make the grid more stable, and help reduce investment into transmission infrastructure.<sup>[9]</sup> The type of service provided by storage depends on who manages the technology, whether the technology is based alongside generation of electricity, within the

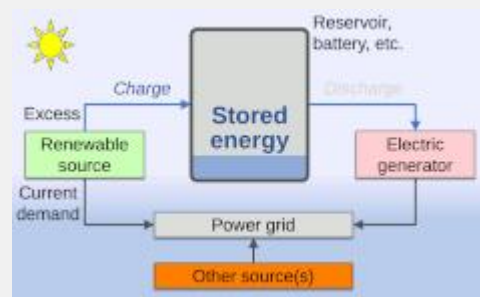
network, or at the side of [consumption](#).<sup>[8]</sup>

Providing short-term flexibility is a key role for energy storage. On the generation side, it can help with the integration of [variable renewable energy](#), storing it when there is an oversupply of wind and solar and electricity prices are low. More generally, it can exploit the changes in prices of electricity over time in the [wholesale market](#), charging when electricity is cheap and selling when it is expensive. It can further help with [grid congestion](#) (where there is insufficient capacity on [transmission lines](#)). Consumers can use storage to use more of their self-produced electricity (for instance from [rooftop solar power](#)).<sup>[8][7]</sup>

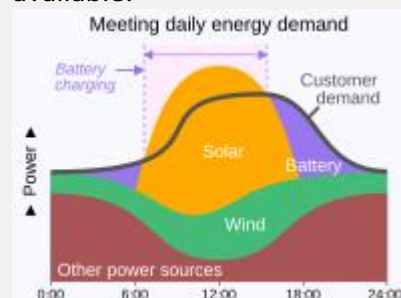
Storage can also be used to provide [essential grid services](#). On the generation side, storage can smooth out the variations in production, for instance for solar and wind. It can assist in a [black start](#) after a [power outage](#). On the network side, these include [frequency regulation](#) (continuously) and [frequency response](#) (after unexpected changes in supply or demand). On the consumption side, storage can help to improve the [quality of the delivered electricity](#) in less stable grids.<sup>[8][10]</sup>

Investment in storage may make some investments in the transmission and [distribution network](#) unnecessary, or may allow them to be scaled down. Additionally, storage can ensure there is sufficient capacity to meet [peak demand](#) within the electricity grid. Finally, in off-grid home systems or [mini-grids](#), electricity storage can help provide [energy access](#) in areas that were previously not connected to the electricity grid.<sup>[8]</sup>

Forms



Energy from sunlight or other renewable energy is converted to potential energy for storage in devices such as electric batteries. The stored potential energy is later converted to electricity that is added to the power grid, even when the original energy source is not available.

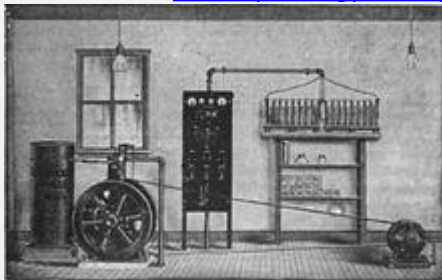


In daytime, different renewable sources provide different amounts of power to the grid. At night, energy is provided by batteries that were charged during the day when renewable energy exceeded customer demand.

Electricity can be stored directly for a short time in capacitors, somewhat longer electrochemically in [batteries](#), and much longer chemically (e.g. hydrogen), mechanically (e.g. pumped hydropower) or as heat.<sup>[11]</sup> The first pumped hydroelectricity was constructed at the end of the 19th century around [the Alps](#) in Italy, Austria, and Switzerland. The technique rapidly expanded during the 1960s to 1980s [nuclear boom](#), due to nuclear power's inability to quickly adapt to changes in electricity demand. In the 21st century, interest in storage surged due to the rise of [sustainable energy sources](#), which are often weather-dependent.<sup>[12]</sup> Commercial batteries have been available for over a century,<sup>[13]</sup> their widespread use in the power grid is more recent, with only 1 GW available in 2013.<sup>[14]</sup>

## Batteries

Main article: [Battery energy storage system](#)



A 900 watt direct current light plant using 16 separate [lead acid battery](#) cells (32 volts) from 1917.<sup>[15]</sup>

## Lithium-ion batteries

Lithium-ion batteries are the most commonly used batteries for grid applications, as of 2024, following the application of batteries in electric vehicles (EVs). In comparison with EVs, grid batteries require less [energy density](#), meaning that more emphasis can be put on costs, the ability to charge and discharge often and lifespan. This has led to a shift towards [lithium iron phosphate batteries](#) (LFP batteries), which are cheaper and last longer than traditional lithium-ion batteries.<sup>[16]</sup>

Costs of batteries are declining rapidly; from 2010 to 2023 costs fell by 90%.<sup>[17]</sup> As of 2024, utility-scale systems account for two thirds of added capacity, and home applications (behind-the-meter) for one third.<sup>[18]</sup> Lithium-ion batteries are highly suited to short-duration storage (<8h) due to cost and degradation associated with high [states of charge](#).<sup>[19]</sup>

## Electric vehicles

Main article: [Vehicle-to-grid](#)



Batteries from old electric cars, such as this [Nissan Leaf](#), can be reused but as of 2024 it is not known whether grid storage or behind the meter storage will be the best application. <sup>[20]</sup>

The [electric vehicle](#) fleet has a large overall battery capacity, which can potentially be used for grid energy storage. This could be in the form of [vehicle-to-grid](#) (V2G), where cars store energy when they are not in use, or by [repurposing](#) batteries from cars at the end of the vehicle's life. Car batteries typically range between 33 and 100 kWh; <sup>[21]</sup> for comparison, a typical upper-middle-class household in Spain might use some 18 kWh in a day. <sup>[22]</sup> By 2030, batteries in electric vehicles may be able to meet all short-term storage demand globally. <sup>[23]</sup>

As of 2024, there have been more than 100 V2G pilot projects globally. <sup>[24]</sup> The effect of V2G charging on battery life can be positive or negative. Increased cycling of batteries can lead to faster degradation, but due to better management of the [state of charge](#) and gentler charging and discharging, V2G might instead increase the lifetime of batteries. <sup>[24][25]</sup> Second-hand batteries may be useable for stationary grid storage for roughly 6 years, when their capacity drops from roughly 80% to 60% of the initial capacity. [LFP batteries](#) are particularly suitable for reusing, as they degrade less than other lithium-ion batteries and recycling is less attractive as their materials are not as valuable. <sup>[24]</sup>

#### Other battery types

In redox [flow batteries](#), energy is stored in liquids, which are placed in two separate tanks. When charging or discharging, the liquids are pumped into a cell with the electrodes. The amount of energy stored (as set by the size of the tanks) can be adjusted separately from the power output (as set by the speed of the pumps). <sup>[26]</sup> Flow batteries have the advantages of low capital cost for charge-discharge duration over 4 h, and of long durability (many years). Flow batteries are inferior to [lithium-ion batteries](#) in terms of [energy efficiency](#), averaging efficiencies between 60% and 75%. [Vanadium redox batteries](#) is most commercially advanced type of flow battery, with roughly 40 companies making them as of 2022. <sup>[27]</sup>

[Sodium-ion batteries](#) are a possible alternative to lithium-ion batteries, as they are less [flammable](#), <sup>[28]</sup> and use cheaper and less critical materials. They have a lower energy density, and possibly a shorter lifespan. If produced at the same scale as lithium-ion batteries, they may become 20% to 30% cheaper. <sup>[26]</sup> [Iron-air batteries](#) may be suitable for even longer

duration storage than flow batteries (weeks), but the technology is not yet mature.<sup>[29]</sup>

#### Technology comparison<sup>[29]</sup>

Technology	Less than 4h	4h to 8h	Days	Weeks	Seasons
<a href="#">Lithium-ion</a>	Yes	Yes	No	No	No
<a href="#">Sodium-ion</a>	Yes	Yes	No	No	No
<a href="#">Vanadium flow</a>	Maybe	Yes	Yes	No	No
<a href="#">Iron-air</a>	No	No	Maybe	Yes	No

#### Electrical

Storage in [supercapacitors](#) works well for applications where a lot of power is needed for short amount of time. In the power grid, they are therefore mostly used in short-term frequency regulation.<sup>[30]</sup>

#### Hydrogen and chemical storage

Main articles: [Hydrogen economy](#) and [Hydrogen storage](#)

See also: [Combined cycle hydrogen power plant](#)

Various [power-to-gas](#) technologies exist that can convert excess electricity into an easier to store chemical. The lowest cost and most efficient one is [hydrogen](#). However, it is easier to use synthetic [methane](#) with existing infrastructure and appliances, as it is very similar to natural gas.<sup>[31]</sup>

As of 2024, there have been a number of demonstration plants where hydrogen is burned in [gas turbines](#), either co-firing with natural gas, or on its own. Similarly, a number of [coal plants](#) have demonstrated it is possible to co-fire [ammonia](#) when burning coal. In 2022, there was also a small pilot to burn pure ammonia in a gas turbine.<sup>[32]</sup> A portion of existing gas turbines are capable of co-firing hydrogen, which means there is, as a lower estimate, 80 GW of capacity ready to burn hydrogen.<sup>[33]</sup>

#### Hydrogen

[Hydrogen](#) can be used as a long-term storage medium.<sup>[34]</sup> [Green hydrogen](#) is produced from the [electrolysis of water](#) and converted back into electricity in an [internal combustion engine](#), or a [fuel cell](#), with a round-trip efficiency of roughly 41%.<sup>[35]</sup> Together with thermal storage, it is expected to be best suited to seasonal energy storage.<sup>[36]</sup>

Hydrogen can be stored aboveground in tanks or underground in larger quantities. Underground storage is easiest in [salt caverns](#), but only a certain number of places have suitable geology.<sup>[37]</sup> Storage in porous rocks, for instance in empty [gas fields](#) and some [aquifers](#), can store hydrogen at a larger scale, but this type of storage may have some drawbacks. For instance, some of the hydrogen may leak, or react into [H<sub>2</sub>S](#) or [methane](#).<sup>[38]</sup>

#### Ammonia

Hydrogen can be converted into ammonia in a reaction with [nitrogen](#) in the [Haber-Bosch process](#). Ammonia, a gas at room temperature, is more expensive to produce than hydrogen. However, it can be stored more cheaply than hydrogen. Tank storage is usually done at between one and ten [times atmospheric pressure](#) and at a temperature of  $-30\text{ }^{\circ}\text{C}$  ( $-22\text{ }^{\circ}\text{F}$ ), in liquid form.<sup>[39]</sup> Ammonia has [multiple uses](#) besides being an energy carrier: it is the basis for the production of many chemicals; the most common use is for fertilizer.<sup>[40]</sup> It can be used for power generation directly, or converted back to hydrogen first. Alternatively, it has potential applications as a fuel in [shipping](#).<sup>[41]</sup>

#### Methane

It is possible to further convert hydrogen into [methane](#) via the [Sabatier reaction](#), a chemical reaction which combines  $\text{CO}_2$  and  $\text{H}_2$ . While the reaction that converts CO from [gasified coal](#) into  $\text{CH}_4$  is mature, the process to form methane out of  $\text{CO}_2$  is less so. Efficiencies of around 80% one-way can be achieved, that is, some 20% of the energy in hydrogen is lost in the reaction.<sup>[42]</sup>

#### Mechanical

##### Flywheel

Main articles: [Flywheel storage power system](#) and [Flywheel energy storage](#)



NASA G2 flywheel

Flywheels store energy in the form of mechanical energy. They are suited to supplying high

levels of electricity over minutes and can also be charged rapidly. They have a long lifetime and can be used in settings with widely varying temperatures. The technology is mature, but more expensive than batteries and supercapacitors and not used frequently.<sup>[43]</sup>

#### Pumped hydro

Main article: [Pumped-storage hydroelectricity](#)



[Mingtan Pumped-Storage Hydro Power Plant](#) dam in [Nantou](#), Taiwan

As of 2023, pumped-storage hydroelectricity (PSH) was the largest form of grid energy storage globally, with an installed capacity of 181 [GW](#), surpassing the combined capacity of utility-scale and behind-the-meter battery storage, which totaled approximately 88 GW.<sup>[44]</sup>

PSH is particularly effective for managing daily fluctuations in energy demand. During periods of low demand, water is pumped to a higher-elevation reservoir, and during peak demand, the stored water is released to generate electricity through turbines.<sup>[45]</sup> The system has an efficiency rate of 75% to 85% and can quickly respond to changes in demand, typically within seconds to minutes.<sup>[46]</sup>

While traditional PSH systems require specific geographical conditions, alternative designs have been proposed. These include using deep [salt caverns](#) or constructing hollow structures on the [seabed](#), where the ocean serves as the upper reservoir.<sup>[45]</sup> However, PSH construction is often expensive, time-consuming, and can have significant environmental and social impacts on nearby communities.<sup>[45]</sup> Installing [floating solar panels](#) on reservoirs, can increase the efficiency of PSH systems. These panels reduce water evaporation and benefit from cooling by the water surface, which also improves their energy generation efficiency.<sup>[47]</sup>

#### Hydroelectric dams



[Fetsui hydroelectric dam](#) in [New Taipei](#), Taiwan

[Hydroelectric dams](#) with large reservoirs can also be operated to provide peak generation at times of peak demand. Water is stored in the reservoir during periods of low demand and released through the plant when demand is higher. While technically no electricity is stored, the net effect is the similar as pumped storage. The amount of storage available in hydroelectric dams is much larger than in pumped storage. Upgrades may be needed so that these dams can respond to variable demand. For instance, additional investment may be needed in transmission lines, or additional turbines may need to be installed to increase the peak output from the dam.<sup>[48]</sup>

Dams usually have multiple purposes. As well as energy generation, they often play a role in [flood defense](#) and protection of ecosystems, recreation, and they supply water for [irrigation](#). This means it is not always possible to change their operation much, but even with low flexibility, they may still play an important role in responding to changes in wind and solar production.<sup>[49]</sup>

Gravity

Main article: [Energy storage § Solid mass gravitational](#)

Alternative [methods that use gravity](#) include storing energy by moving large solid masses upward against gravity. This can be achieved inside old mine shafts<sup>[50]</sup> or in specially constructed towers where heavy weights are [winched](#) up to store energy and allowed a controlled descent to release it.<sup>[51][52]</sup>

Compressed air

Main article: [Compressed-air energy storage](#)

Compressed air energy storage (CAES) stores electricity by compressing air. The compressed air is typically stored in large underground caverns. The expanding air can be used to drive turbines, converting the energy back into electricity. As [air cools when expanding](#), some heat needs to be added in this stage to prevent freezing. This can be provided by a low-carbon source, or in the case of advanced CAES, by reusing the heat that is released when air is compressed. As of 2023, there are three advanced CAES projects in operation in China.<sup>[53]</sup> Typical efficiencies of advanced CAES are between 60% and 80%.<sup>[54]</sup>

Liquid air or CO<sub>2</sub>

Main article: [Cryogenic energy storage](#)

Another electricity storage method is to compress and cool air, turning it into [liquid air](#), which can be stored and expanded when needed, turning a turbine to generate electricity. This is called liquid air energy storage (LAES).<sup>[55]</sup> The air would be cooled to temperatures of

–196 °C (–320.8 °F) to become liquid. Like with compressed air, heat is needed for the expansion step. In the case of LAES, low-grade industrial heat can be used for this.<sup>[43]</sup> Energy efficiency for LAES lies between 50% and 70%. As of 2023, LAES is moving from pre-commercial to commercial.<sup>[56]</sup> An alternative is the compression of CO<sub>2</sub> to store electricity.<sup>[57]</sup>

## Thermal

Main article: [Thermal energy storage](#)

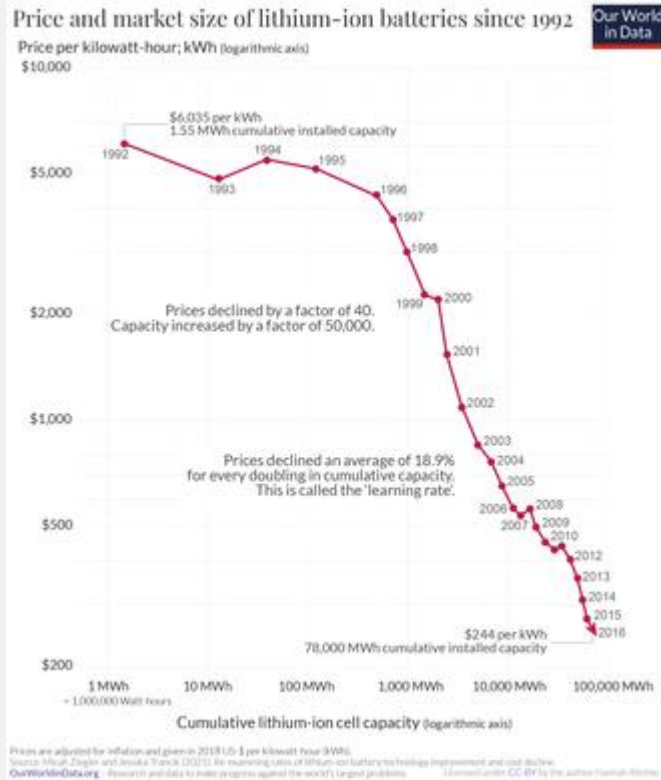
Electricity can be directly stored thermally with a [Carnot battery](#). A Carnot battery is a type of energy storage system that stores electricity in heat storage and converts the stored heat back to electricity via [thermodynamic cycles](#) (for instance, a turbine). While less efficient than pumped hydro or battery storage, this type of system is expected to be cheap and can provide long-duration storage.<sup>[58][59]</sup> A [pumped-heat electricity storage](#) system is a Carnot battery that uses a [reversible heat pump](#) to convert the electricity into heat.<sup>[60]</sup> It usually stores the energy in both a hot and cold reservoir. To achieve decent efficiencies (>50%), the temperature ratio between the two must reach a factor of 5.<sup>[61]</sup>

Thermal energy storage is also used in combination with [concentrated solar power](#) (CSP). In CSP, solar energy is first converted into heat, and then either directly converted into electricity or first stored. The energy is released when there is little or no sunshine.<sup>[62]</sup> This means that CSP can be used as a [dispatchable \(flexible\)](#) form of generation. The energy in a CSP system can for instance be stored in [molten salts](#) or in a solid medium such as sand.<sup>[63]</sup>

Finally, [heating and cooling systems](#) in [buildings](#) can be controlled to store thermal energy in either the building's mass or dedicated thermal storage tanks. This thermal storage can provide load-shifting or even more complex [ancillary services](#) by increasing power consumption (charging the storage) during off-peak times and lowering power consumption (discharging the storage) during higher-priced peak times.<sup>[64]</sup>

## Economics

### Costs



[Experience curve](#) of lithium-ion

batteries: the price of batteries dropped by 97% in three decades. <sup>[65][66]</sup>

The [levelized cost of storing electricity](#) (LCOS) is a measure of the lifetime costs of storing electricity per [MWh](#) of electricity discharged. It includes investment costs, but also operational costs and charging costs. <sup>[67]</sup> It depends highly on storage type and purpose; as subsecond-scale [frequency regulation](#), minute/hour-scale peaker plants, or day/week-scale season storage. <sup>[68][69][70]</sup>

For power applications (for instance around [ancillary services](#) or [black starts](#)), a similar metric is the [annuitized capacity cost](#) (ACC), which measures the lifetime costs per kW. ACC is lowest when there are few cycles (<300) and when the discharge is less than one hour. This is because the technology is reimbursed only when it provides spare capacity, not when it is discharged. <sup>[71]</sup>

The cost of storage is coming down following technology-dependent [experience curves](#), the price drop for each doubling in cumulative capacity (or experience). Lithium-ion battery prices fast: the price utilities pay for them falls 19% with each doubling of capacity. Hydrogen production via electrolysis has a similar learning rate, but it is much more uncertain. Vanadium-flow batteries typically get 14% cheaper for each doubling of capacity. Pumped hydropower has not seen prices fall much with increased experience. <sup>[4]</sup>

Market and system value

There are four categories of services which provide economic value for storage: those

related to power quality (such as frequency regulation), reliability (ensuring peak demand can be met), better use of assets in the system (e.g. avoiding transmission investments) and [arbitrage](#) (exploiting price differences over time). Before 2020, most value for storage was in providing power quality services. Arbitrage is the service with the largest economic potential for storage applications.<sup>[72]</sup>

Storage requirements based on the share of variable renewable energy (VRE). For energy storage, this is the energy stored at a given time, not the total over the year<sup>[73]</sup>

VRE share	Power (% of peak demand)	Energy storage (% of annual demand)
50%	Less than 20%	0.02%
80%	20–50%	0.03–0.1%
90%	25–75%	0.05–0.2%

In systems with under 40% of variable renewables, only short-term storage (of less than 4 hours) is needed for integration. When the share of variable renewables climbs to 80%, medium-duration storage (between 4 and 16 hours, for instance [compressed air](#)) is needed. Above 90%, large-scale [long-duration storage](#) is required.<sup>[74]</sup> The economics of long-duration storage is challenging even then, as the costs are high. Alternative flexibility options, such as demand response, network expansions or flexible generation ([geothermal](#) or fossil gas with [carbon capture and storage](#)) may be lower-cost.<sup>[75]</sup>

Like with renewables, storage will "[cannibalise](#)" its own income, but even more strongly. That is, with more storage on the market, there is less of an opportunity to do arbitrage or deliver other services to the grid.<sup>[76]</sup> How markets are designed impacts revenue potential too. The income from arbitrage is quite variable between years, whereas markets that have [capacity payments](#) likely show less volatility.<sup>[77]</sup>

Electricity storage is not 100% efficient, so more electricity needs to be bought than can be sold. This implies that if there is only a small variation in price, it may not be economical to charge and discharge. For instance, if the storage application is 75% efficient, the price at which the electricity is sold needs to be at least 1.33 higher than the price for which it was bought.<sup>[78]</sup> Typically, electricity prices vary most between day and night, which means that storage up to 8 hours has relatively high potential for profit.

- [Article](#)
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#### Appearance

##### Text

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☐ Small

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☐ Standard

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☐ Automatic

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From Wikipedia, the free encyclopedia

### Why cogeneration is more efficient than conventional coal power plants

Comparing the energy efficiency of cogeneration with conventional coal power plant and heating system

Source: ADEE

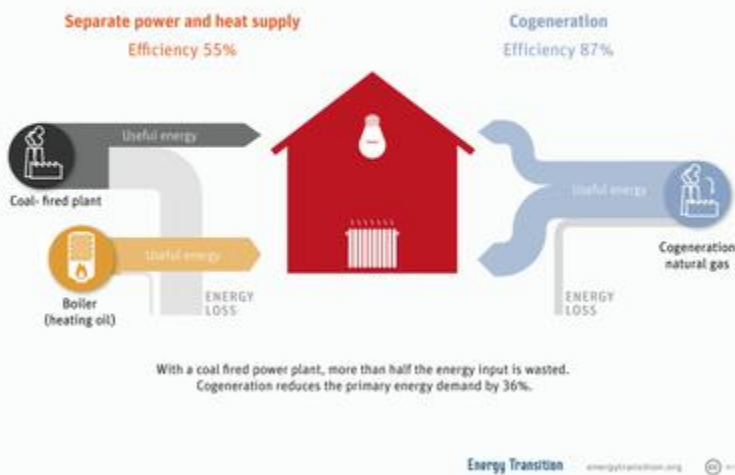


Diagram comparing losses

from conventional generation vs. cogeneration

Part of a series on



[Sustainable energy](#)



[Energy conservation](#)

## [Renewable energy](#)

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Cogeneration or combined heat and power (CHP) is the use of a [heat engine<sup>\[1\]</sup>](#) or [power station](#) to [generate electricity](#) and useful heat at the same time.

Cogeneration is a more efficient use of fuel or heat, because otherwise-[wasted heat](#) from electricity generation is put to some productive use. Combined heat and power (CHP) plants recover otherwise wasted [thermal energy](#) for [heating](#). This is also called combined heat and power district heating. Small CHP plants are an example of [decentralized energy](#).<sup>[2]</sup> By-product heat at moderate temperatures (100–180 °C (212–356 °F) can also be used in [absorption refrigerators](#) for cooling.

The supply of high-temperature heat first drives a [gas](#) or [steam turbine](#)-powered generator. The resulting low-temperature waste heat is then used for water or space heating. At smaller scales (typically below 1 MW), a [gas engine](#) or [diesel engine](#) may be used. Cogeneration is also common with [geothermal power plants](#) as they often produce relatively [low grade heat](#). [Binary cycles](#) may be necessary to reach acceptable [thermal efficiency](#) for electricity generation at all. Cogeneration is less commonly employed in [nuclear power plants](#) as [NIMBY](#) and safety considerations have often kept them further from population centers than comparable chemical power plants and [district heating](#) is less efficient in lower population density areas due to transmission losses.

Cogeneration was practiced in some of the earliest installations of electrical generation. Before central stations distributed power, industries generating their own power used exhaust steam for process heating. Large office and apartment buildings, hotels, and stores commonly generated their own power and used waste steam for building heat. Due to the high cost of early purchased power, these CHP operations continued for many years after utility electricity became available.<sup>[3]</sup>

Overview



[Masnedø](#) CHP power station in [Denmark](#).

This station burns straw as fuel. The adjacent greenhouses are heated by [district heating](#) from the plant.

Many process industries, such as [chemical plants](#), [oil refineries](#) and pulp and [paper mills](#), require large amounts of [process heat](#) for such operations as [chemical reactors](#), distillation columns, steam driers and other uses. This heat, which is usually used in the form of steam, can be generated at the typically low pressures used in heating, or can be generated at much higher pressure and passed through a turbine first to generate electricity. In the turbine the steam pressure and temperature is lowered as the internal energy of the steam is converted to work. The lower-pressure steam leaving the turbine can then be used for process heat.

Steam turbines at [thermal power stations](#) are normally designed to be fed high-pressure steam, which exits the turbine at a condenser operating a few degrees above ambient temperature and at a few millimeters of mercury absolute pressure. (This is called a *condensing* turbine.) For all practical purposes this steam has negligible useful energy before it is condensed. Steam turbines for cogeneration are designed for *extraction* of some steam at lower pressures after it has passed through a number of turbine stages, with the un-extracted steam going on through the turbine to a condenser. In this case, the extracted steam causes a mechanical [power loss](#) in the downstream stages of the turbine. Or they are designed, with or without extraction, for final exhaust at *back pressure* (non-condensing).<sup>[4][5]</sup> The extracted or exhaust steam is used for process heating. Steam at ordinary process heating conditions still has a considerable amount of [enthalpy](#) that could be used for power generation, so cogeneration has an [opportunity cost](#).

A typical power generation turbine in a [paper mill](#) may have extraction pressures of 160 and 60 psi (1.10 and 0.41 MPa). A typical back pressure may be 60 psi (0.41 MPa). In practice these pressures are custom designed for each facility. Conversely, simply generating process steam for industrial purposes instead of high enough pressure to generate power at the top end also has an opportunity cost (See: [Steam supply and exhaust conditions](#)). The capital and operating cost of high-pressure boilers, turbines, and generators is substantial. This equipment is normally operated [continuously](#), which usually limits self-generated power to large-scale operations.



A cogeneration plant in [Metz, France](#). The 45 MW boiler uses waste wood [biomass](#) as an energy source, providing electricity and heat for 30,000 [dwellings](#).

A [combined cycle](#) (in which several thermodynamic cycles produce electricity), may also be used to extract heat using a heating system as [condenser](#) of the power plant's [bottoming cycle](#). For example, the RU-25 [MHD generator](#) in [Moscow](#) heated a boiler for a conventional steam powerplant, whose condensate was then used for space heat. A more modern system might use a [gas turbine](#) powered by [natural gas](#), whose exhaust powers a steam plant, whose condensate provides heat. Cogeneration plants based on a combined cycle power unit can have thermal efficiencies above 80%.

The viability of CHP (sometimes termed utilisation factor), especially in smaller CHP installations, depends on a good baseload of operation, both in terms of an on-site (or near site) electrical demand and heat demand. In practice, an exact match between the heat and electricity needs rarely exists. A CHP plant can either meet the need for heat (*heat driven operation*) or be run as a [power plant](#) with some use of its waste heat, the latter being less advantageous in terms of its utilisation factor and thus its overall efficiency. The viability can be greatly increased where opportunities for trigeneration exist. In such cases, the heat from the CHP plant is also used as a primary energy source to deliver cooling by means of an [absorption chiller](#).

CHP is most efficient when heat can be used on-site or very close to it. Overall efficiency is reduced when the heat must be transported over longer distances. This requires heavily insulated pipes, which are expensive and inefficient; whereas electricity can be transmitted along a comparatively simple wire, and over much longer distances for the same energy loss.

A car engine becomes a CHP plant in winter when the reject heat is useful for warming the interior of the vehicle. The example illustrates the point that deployment of CHP depends on heat uses in the vicinity of the heat engine.

Thermally [enhanced oil recovery](#) (TEOR) plants often produce a substantial amount of excess electricity. After generating electricity, these plants pump leftover steam into heavy

oil wells so that the oil will flow more easily, increasing production.

Cogeneration plants are commonly found in [district heating](#) systems of cities, [central heating](#) systems of larger buildings (e.g. hospitals, hotels, prisons) and are commonly used in the industry in thermal production processes for process water, cooling, steam production or [CO<sub>2</sub>](#) fertilization.



[Rostock Power Station](#), a bituminous coal-fired combined heat and power plant in Germany

*Trigeneration or combined cooling, heat and power (CCHP)* refers to the simultaneous generation of electricity and useful heating and cooling from the combustion of a fuel or a solar heat collector. The terms *cogeneration* and *trigeneration* can also be applied to the power systems simultaneously generating electricity, heat, and industrial chemicals (e.g., [syngas](#)). Trigeneration differs from cogeneration in that the [waste heat](#) is used for both heating and cooling, typically in an absorption refrigerator. Combined cooling, heat, and power systems can attain higher overall efficiencies than cogeneration or traditional power plants. In the United States, the application of trigeneration in buildings is called building cooling, heating, and power. Heating and cooling output may operate concurrently or alternately depending on need and system construction.

Types of plants



[Hanasaari Power Plant](#), a [coal-fired](#) cogeneration power plant in [Helsinki, Finland](#)

Topping cycle plants primarily produce electricity from a steam turbine. Partly expanded steam is then condensed in a heating condensor at a temperature level that is suitable e.g. [district heating](#) or [water desalination](#).

[Bottoming cycle](#) plants produce high temperature heat for industrial processes, then a [waste heat recovery](#) boiler feeds an electrical plant. Bottoming cycle plants are only used in industrial processes that require very high temperatures such as furnaces for glass and metal manufacturing, so they are less common.

Large cogeneration systems provide heating water and power for an industrial site or an entire town. Common CHP plant types are:

- [Gas turbine](#) CHP plants using the waste heat in the flue gas of gas turbines. The fuel used is typically [natural gas](#).
- [Gas engine](#) CHP plants use a reciprocating gas engine, which is generally more competitive than a gas turbine up to about 5 MW. The gaseous fuel used is normally [natural gas](#). These plants are generally manufactured as fully packaged units that can be installed within a plantroom or external plant compound with simple connections to the site's gas supply, electrical distribution network and heating systems. Typical outputs and efficiencies see <sup>[6]</sup> Typical large example see <sup>[7]</sup>
- [Biofuel engine](#) CHP plants use an adapted reciprocating gas engine or [diesel engine](#), depending upon which biofuel is being used, and are otherwise very similar in design to a Gas engine CHP plant. The advantage of using a biofuel is one of reduced [fossil fuel](#) consumption and thus reduced carbon emissions. These plants are generally manufactured as fully packaged units that can be installed within a plantroom or external plant compound with simple connections to the site's electrical distribution and heating systems. Another variant is the [wood gasifier](#) CHP plant whereby a wood pellet or wood chip biofuel is [gasified](#) in a zero oxygen high temperature environment; the resulting gas is then used to power the gas engine.
- [Combined cycle](#) power plants adapted for CHP
- [Molten-carbonate fuel cells](#) and [solid oxide fuel cells](#) have a hot exhaust, very suitable for heating.
- [Steam turbine](#) CHP plants that use the heating system as the [steam](#) condenser for the steam turbine
- [Nuclear power plants](#), similar to other steam turbine power plants, can be fitted with extractions in the turbines to bleed partially expanded steam to a heating system. With a heating system temperature of 95 °C it is possible to extract about 10 MW heat for every MW electricity lost. With a temperature of 130 °C the gain is slightly smaller, about 7 MW for every MWe lost.<sup>[8]</sup> A review of cogeneration options is in <sup>[9]</sup> Czech research team proposed a "Teplator" system where heat from spent fuel rods is recovered for the purpose of residential heating.<sup>[10]</sup>

Smaller cogeneration units may use a [reciprocating engine](#) or [Stirling engine](#). The heat is removed from the exhaust and radiator. The systems are popular in small sizes because small gas and diesel engines are less expensive than small gas- or oil-fired steam-electric plants.

Some cogeneration plants are fired by [biomass](#),<sup>[11]</sup> or industrial and [municipal solid waste](#)

(see [incineration](#)). Some CHP plants use waste gas as the fuel for electricity and heat generation. Waste gases can be gas from [animal waste](#), [landfill gas](#), [gas from coal mines](#), [sewage gas](#), and combustible industrial waste gas.<sup>[12]</sup>

Some cogeneration plants combine gas and solar [photovoltaic](#) generation to further improve technical and environmental performance.<sup>[13]</sup> Such hybrid systems can be scaled down to the building level<sup>[14]</sup> and even individual homes.<sup>[15]</sup>

#### MicroCHP

[Micro combined heat and power](#) or 'Micro cogeneration' is a so-called [distributed energy resource](#) (DER). The installation is usually less than 5 kW<sub>e</sub> in a house or small business. Instead of burning fuel to merely heat space or water, some of the energy is converted to electricity in addition to heat. This electricity can be used within the home or business or, if permitted by the grid management, sold back into the electric power grid.

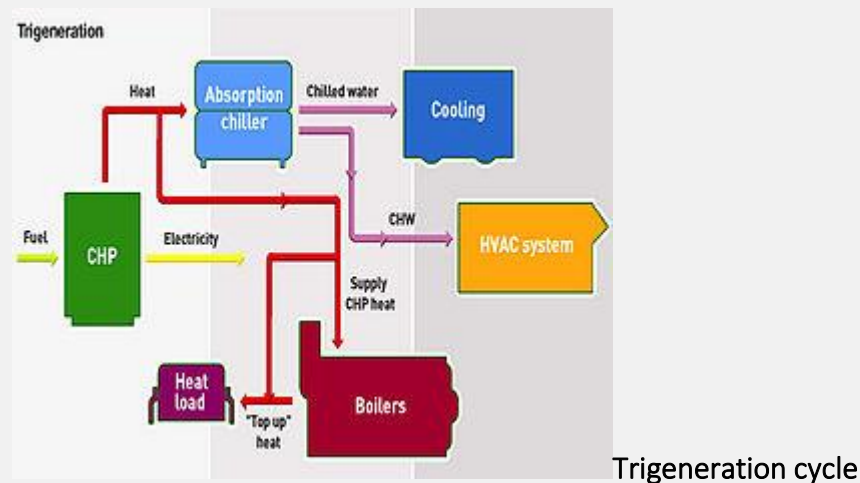
Delta-ee consultants stated in 2013 that with 64% of global sales the [fuel cell](#) micro-combined heat and power passed the conventional systems in sales in 2012.<sup>[16]</sup> 20,000 units were sold in [Japan](#) in 2012 overall within the Ene Farm project. With a [Lifetime](#) of around 60,000 hours. For [PEM fuel cell](#) units, which shut down at night, this equates to an estimated lifetime of between ten and fifteen years.<sup>[17]</sup> For a price of \$22,600 before installation.<sup>[18]</sup> For 2013 a state subsidy for 50,000 units is in place.<sup>[17]</sup>

MicroCHP installations use five different technologies: [microturbines](#), [internal combustion engines](#), [stirling engines](#), closed-cycle [steam engines](#), and [fuel cells](#). One author indicated in 2008 that MicroCHP based on Stirling engines is the most cost-effective of the so-called microgeneration technologies in abating carbon emissions.<sup>[19]</sup> A 2013 UK report from Ecuity Consulting stated that MCHP is the most cost-effective method of using gas to generate energy at the domestic level.<sup>[20][21]</sup> However, advances in reciprocation engine technology are adding efficiency to CHP plants, particularly in the [biogas](#) field.<sup>[22]</sup> As both MiniCHP and CHP have been shown to reduce emissions<sup>[23]</sup> they could play a large role in the field of CO<sub>2</sub> reduction from buildings, where more than 14% of emissions can be saved using CHP in buildings.<sup>[24]</sup> The University of Cambridge reported a cost-effective steam engine MicroCHP prototype in 2017 which has the potential to be commercially competitive in the following decades.<sup>[25]</sup> Quite recently, in some private homes, [fuel cell micro-CHP plants](#) can now be found, which can operate on hydrogen, or other fuels as natural gas or LPG.<sup>[26][27]</sup> When running on natural gas, it relies on [steam reforming](#) of natural gas to convert the natural gas to hydrogen prior to use in the fuel cell. This hence still emits CO<sub>2</sub> (see reaction) but (temporarily) running on this can be a good solution until the point where the hydrogen is starting to be distributed through the (natural gas) piping system.

Another MicroCHP example is a natural gas or propane fueled Electricity Producing Condensing Furnace. It combines the fuel saving technique of cogeneration meaning producing electric power and useful heat from a single source of combustion. The

condensing [furnace](#) is a [forced-air gas](#) system with a secondary heat exchanger that allows heat to be extracted from combustion products down to the ambient temperature along with recovering heat from the water vapor. The chimney is replaced by a water drain and vent to the side of the building.

## Trigeneration



A plant producing electricity, heat and cold is called a trigeneration<sup>[28]</sup> or polygeneration plant. Cogeneration systems linked to [absorption chillers](#) or [adsorption chillers](#) use waste heat for [refrigeration](#).<sup>[29]</sup>

## Combined heat and power district heating

See also: [District heating](#)

In the [United States](#), [Consolidated Edison](#) distributes 66 billion kilograms of 350 °F (177 °C) steam each year through its seven cogeneration plants to 100,000 buildings in [Manhattan](#)—the biggest steam district in the United States. The peak delivery is 10 million pounds per hour (or approximately 2.5 GW).<sup>[30][31]</sup>

## Industrial CHP

Cogeneration is still common in [pulp and paper mills](#), refineries and chemical plants. In this "industrial cogeneration/CHP", the heat is typically recovered at higher temperatures (above 100 °C) and used for process steam or drying duties. This is more valuable and flexible than low-grade waste heat, but there is a slight loss of power generation. The increased focus on [sustainability](#) has made industrial CHP more attractive, as it substantially reduces [carbon footprint](#) compared to generating steam or burning fuel on-site and importing electric power from the grid.

Smaller industrial co-generation units have an output capacity of 5–25 MW and represent a

viable off-grid option for a variety of remote applications to reduce carbon emissions.<sup>[32]</sup>

Utility pressures versus self generated industrial

Industrial cogeneration plants normally operate at much lower boiler pressures than utilities. Among the reasons are:

1. Cogeneration plants face possible contamination of returned condensate. Because boiler feed water from cogeneration plants has much lower return rates than 100% condensing power plants, industries usually have to treat proportionately more boiler make up water. Boiler feed water must be completely oxygen free and de-mineralized, and the higher the pressure the more critical the level of purity of the feed water.<sup>[5]</sup>
2. Utilities are typically larger scale power than industry, which helps offset the higher capital costs of high pressure.
3. Utilities are less likely to have sharp load swings than industrial operations, which deal with shutting down or starting up units that may represent a significant percent of either steam or power demand.

Heat recovery steam generators

A [heat recovery steam generator](#) (HRSG) is a steam boiler that uses hot [exhaust gases](#) from the [gas turbines](#) or [reciprocating engines](#) in a CHP plant to heat up water and generate [steam](#). The steam, in turn, drives a [steam turbine](#) or is used in industrial processes that require heat.

HRSGs used in the CHP industry are distinguished from conventional steam generators by the following main features:

- The HRSG is designed based upon the specific features of the gas turbine or reciprocating engine that it will be coupled to.
- Since the exhaust gas temperature is relatively low, heat transmission is accomplished mainly through [convection](#).
- The exhaust gas velocity is limited by the need to keep head losses down. Thus, the transmission coefficient is low, which calls for a large heating surface area.
- Since the temperature difference between the hot gases and the fluid to be heated (steam or water) is low, and with the heat transmission coefficient being low as well, the evaporator and economizer are designed with plate fin heat exchangers.

Cogeneration using biomass

[Biomass](#) refers to any plant or animal matter in which it is possible to be reused as a source of heat or electricity, such as [sugarcane](#), vegetable oils, wood, organic waste and residues from the food or [agricultural](#) industries. Brazil is now considered a world reference in terms

of energy generation from biomass.<sup>[33]</sup>

A growing sector in the use of biomass for power generation is the sugar and alcohol sector, which mainly uses sugarcane bagasse as fuel for [thermal](#) and [electric power](#) generation.<sup>[34]</sup>

Power cogeneration in the sugar and alcohol sector

In the sugarcane industry, cogeneration is fueled by the [bagasse](#) residue of sugar refining, which is burned to produce steam. Some steam can be sent through a [turbine](#) that turns a generator, producing electric power.<sup>[35]</sup>

Energy cogeneration in sugarcane industries located in Brazil is a practice that has been growing in last years. With the adoption of energy cogeneration in the sugar and alcohol sector, the sugarcane industries are able to supply the electric energy demand needed to operate, and generate a surplus that can be commercialized.<sup>[36][37]</sup>

Advantages of the cogeneration using sugarcane bagasse

In comparison with the electric power generation by means of fossil fuel-based [thermoelectric](#) plants, such as [natural gas](#), the energy generation using sugarcane bagasse has environmental advantages due to the reduction of [CO<sub>2</sub>](#) emissions.<sup>[38]</sup>

In addition to the environmental advantages, cogeneration using sugarcane bagasse presents advantages in terms of efficiency comparing to thermoelectric generation, through the final destination of the energy produced. While in thermoelectric generation, part of the heat produced is lost, in cogeneration this heat has the possibility of being used in the production processes, increasing the overall efficiency of the process.<sup>[38]</sup>

Disadvantages of the cogeneration using sugarcane bagasse

In sugarcane cultivation, is usually used potassium source's containing high concentration of [chlorine](#), such as [potassium chloride](#) (KCl). Considering that KCl is applied in huge quantities, sugarcane ends up absorbing high concentrations of chlorine.<sup>[39]</sup>

Due to this absorption, when the sugarcane bagasse is burned in the power cogeneration, dioxins <sup>[39]</sup> and methyl chloride <sup>[40]</sup> ends up being emitted. In the case of dioxins, these substances are considered very toxic and cancerous.<sup>[41][42][43]</sup>

In the case of methyl chloride, when this substance is emitted and reaches the [stratosphere](#), it ends up being very harmful for the [ozone](#) layer, since chlorine when combined with the ozone molecule generates a catalytic reaction leading to the breakdown of ozone links.<sup>[40]</sup>

After each reaction, chlorine starts a destructive cycle with another ozone molecule. In this way, a single chlorine atom can destroy thousands of ozone molecules. As these molecules

are being broken, they are unable to absorb the [ultraviolet rays](#). As a result, the [UV radiation](#) is more intense on Earth and there is a worsening of [global warming](#).<sup>[40]</sup>

#### Comparison with a heat pump

A [heat pump](#) may be compared with a CHP unit as follows. If, to supply thermal energy, the exhaust steam from the turbo-generator must be taken at a higher temperature than the system would produce most electricity at, the lost electrical generation is *as if* a heat pump were used to provide the same heat by taking electrical power from the generator running at lower output temperature and higher efficiency.<sup>[44]</sup> Typically for every unit of electrical power lost, then about 6 units of heat are made available at about 90 °C (194 °F). Thus CHP has an effective [Coefficient of Performance \(COP\)](#) compared to a heat pump of 6.<sup>[45]</sup> However, for a remotely operated heat pump, losses in the electrical distribution network would need to be considered, of the order of 6%. Because the losses are proportional to the square of the current, during peak periods losses are much higher than this and it is likely that widespread (i.e. citywide application of heat pumps) would cause overloading of the distribution and transmission grids unless they were substantially reinforced.

It is also possible to run a heat driven operation combined with a heat pump, where the excess electricity (as heat demand is the defining factor on se<sup>[clarification needed]</sup>) is used to drive a heat pump. As heat demand increases, more electricity is generated to drive the heat pump, with the waste heat also heating the heating fluid.

As the efficiency of heat pumps depends on the difference between hot end and cold end temperature (efficiency rises as the difference decreases) it may be worthwhile to combine even relatively low grade waste heat otherwise unsuitable for home heating with heat pumps. For example, a large enough reservoir of cooling water at 15 °C (59 °F) can significantly improve efficiency of heat pumps drawing from such a reservoir compared to [air source heat pumps](#) drawing from cold air during a –20 °C (–4 °F) night. In the summer when there's both demand for [air conditioning](#) and warm water, the same water may even serve as both a "dump" for the waste heat rejected by a/c units and as a "source" for heat pumps providing warm water. Those considerations are behind what is sometimes called "cold district heating" using a "heat" source whose temperature is well below those usually employed in district heating.<sup>[46]</sup>

#### Distributed generation

Most industrial countries generate the majority of their electrical power needs in large centralized facilities with capacity for large electrical power output. These plants benefit from economy of scale, but may need to transmit electricity across long distances causing transmission losses. Cogeneration or trigeneration production is subject to limitations in the local demand and thus may sometimes need to reduce (e.g., heat or cooling production to match the demand). An example of cogeneration with trigeneration applications in a major

city is the [New York City steam system](#).

Thermal efficiency

Every heat engine is subject to the theoretical efficiency limits of the [Carnot cycle](#) or subset [Rankine cycle](#) in the case of steam turbine power plants or [Brayton cycle](#) in gas turbine with steam turbine plants. Most of the efficiency loss with steam power generation is associated with the [latent heat of vaporization](#) of steam that is not recovered when a turbine exhausts its low temperature and pressure steam to a condenser. (Typical steam to condenser would be at a few millimeters absolute pressure and on the order of 5 °C (41 °F) hotter than the cooling water temperature, depending on the condenser capacity.) In cogeneration this steam exits the turbine at a higher temperature where it may be used for process heat, building heat or cooling with an [absorption chiller](#). The majority of this heat is from the [latent heat of vaporization](#) when the steam condenses.

[Thermal efficiency](#) in a cogeneration system is defined as:

Where:

- $\eta_{th}$  = Thermal efficiency
- $W_{tot}$  = Total work output by all systems
- $Q_{in}$  = Total heat input into the system

Heat output may also be used for cooling (for example, in summer), thanks to an absorption chiller. If cooling is achieved in the same time, [thermal efficiency](#) in a trigeneration system is defined as:

Where:

- $\eta_{th}$  = Thermal efficiency
- $W_{tot}$  = Total work output by all systems
- $Q_{in}$  = Total heat input into the system

Typical cogeneration models have losses as in any system. The energy distribution below is

represented as a percent of total input energy:<sup>[47]</sup>

- Electricity = 45%
- Heat + Cooling = 40%
- Heat losses = 13%
- Electrical line losses = 2%

Conventional central coal- or nuclear-powered power stations convert about 33–45% of their input heat to electricity.<sup>[48][5]</sup> [Brayton cycle](#) power plants operate at up to 60% efficiency. In the case of conventional power plants, approximately 10-15% of this heat is lost up the stack of the boiler. Most of the remaining heat emerges from the turbines as low-grade waste heat with no significant local uses, so it is usually rejected to the environment, typically to cooling water passing through a condenser.<sup>[5]</sup> Because turbine exhaust is normally just above ambient temperature, some potential power generation is sacrificed in rejecting higher-temperature steam from the turbine for cogeneration purposes.<sup>[49]</sup>

For cogeneration to be practical power generation and end use of heat must be in relatively close proximity (<2 km typically). Even though the efficiency of a small distributed electrical generator may be lower than a large central power plant, the use of its waste heat for local heating and cooling can result in an overall use of the primary fuel supply as great as 80%.<sup>[48]</sup> This provides substantial financial and environmental benefits.

Costs

See also: [Cost of electricity by source](#)

Typically, for a gas-fired plant the fully installed cost per kW electrical is around £400/kW (US\$577), which is comparable with large central power stations.<sup>[50]</sup>

History

Cogeneration in Europe



A cogeneration thermal power plant in [Ferrera Erbognone \(PV\), Italy](#)



This section needs to be **updated**. Please help update this article to reflect recent events or newly available information. (May 2021)

The [EU](#) has actively incorporated cogeneration into its energy policy via the [CHP Directive](#). In September 2008 at a hearing of the European Parliament's Urban Lodgment Intergroup, Energy Commissioner Andris Piebalgs is quoted as saying, “security of supply really starts with [energy efficiency](#).”<sup>[51]</sup> Energy efficiency and cogeneration are recognized in the opening paragraphs of the European Union's Cogeneration Directive 2004/08/EC. This directive intends to support cogeneration and establish a method for calculating cogeneration abilities per country. The development of cogeneration has been very uneven over the years and has been dominated throughout the last decades by national circumstances.

The European Union generates 11% of its electricity using cogeneration.<sup>[52]</sup> However, there is large difference between Member States with variations of the energy savings between 2% and 60%. Europe has the three countries with the world's most intensive cogeneration economies: Denmark, the Netherlands and Finland.<sup>[53]</sup> Of the 28.46 TWh of electrical power generated by conventional thermal power plants in Finland in 2012, 81.80% was cogeneration.<sup>[54]</sup>

Other European countries are also making great efforts to increase efficiency. Germany reported that at present, over 50% of the country's total electricity demand could be provided through cogeneration. So far, Germany has set the target to double its electricity cogeneration from 12.5% of the country's electricity to 25% of the country's electricity by 2020 and has passed supporting legislation accordingly.<sup>[55]</sup> The UK is also actively supporting combined heat and power. In light of UK's goal to achieve a 60% reduction in carbon dioxide emissions by 2050, the government has set the target to source at least 15% of its government electricity use from CHP by 2010.<sup>[56]</sup> Other UK measures to encourage CHP growth are financial incentives, grant support, a greater regulatory framework, and government leadership and partnership.

According to the IEA 2008 modeling of cogeneration expansion for the G8 countries, the expansion of cogeneration in France, Germany, Italy and the UK alone would effectively double the existing primary fuel savings by 2030. This would increase Europe's savings from today's 155.69 Twh to 465 Twh in 2030. It would also result in a 16% to 29% increase in each country's total cogenerated electricity by 2030.

Governments are being assisted in their CHP endeavors by organizations like [COGEN Europe](#) who serve as an information hub for the most recent updates within Europe's energy policy. COGEN is Europe's umbrella organization representing the interests of the cogeneration industry.

The European [public-private partnership Fuel Cells and Hydrogen Joint Undertaking Seventh Framework Programme](#) project ene.field deploys in 2017<sup>[57]</sup> up 1,000 residential fuel cell Combined Heat and Power ([micro-CHP](#)) installations in 12 states. Per 2012 the first

2 installations have taken place.<sup>[58][59][60]</sup>

#### Cogeneration in the United Kingdom

In the [United Kingdom](#), the *Combined Heat and Power Quality Assurance* scheme regulates the combined production of heat and power. It was introduced in 1996. It defines, through calculation of inputs and outputs, "Good Quality CHP" in terms of the achievement of primary energy savings against conventional separate generation of heat and electricity. Compliance with Combined Heat and Power Quality Assurance is required for cogeneration installations to be eligible for government subsidies and tax incentives.<sup>[61]</sup>

#### Cogeneration in the United States



The 250 [MW Kendall Cogeneration Station](#) plant in [Cambridge, Massachusetts](#)

Perhaps the first modern use of [energy recycling](#) was done by [Thomas Edison](#). His 1882 [Pearl Street Station](#), the world's first commercial power plant, was a combined heat and power plant, producing both electricity and thermal energy while using waste heat to warm neighboring buildings.<sup>[62]</sup> Recycling allowed Edison's plant to achieve approximately 50 percent efficiency.

By the early 1900s, regulations emerged to promote rural electrification through the construction of centralized plants managed by regional utilities. These regulations not only promoted electrification throughout the countryside, but they also discouraged decentralized power generation, such as cogeneration.

By 1978, Congress recognized that efficiency at central power plants had stagnated and sought to encourage improved efficiency with the [Public Utility Regulatory Policies Act](#) (PURPA), which encouraged utilities to buy power from other energy producers.

Cogeneration plants proliferated, soon producing about 8% of all energy in the United States.<sup>[63]</sup> However, the bill left implementation and enforcement up to individual states, resulting in little or nothing being done in many parts of the country.<sup>[citation needed]</sup>

The [United States Department of Energy](#) has an aggressive goal of having CHP constitute

20% of generation capacity by 2030.<sup>[citation needed]</sup> Eight Clean Energy Application Centers<sup>[64]</sup> have been established across the nation. Their mission is to develop the required technology application knowledge and educational infrastructure necessary to lead "clean energy" (combined heat and power, waste heat recovery, and district energy) technologies as viable energy options and reduce any perceived risks associated with their implementation. The focus of the Application Centers is to provide an outreach and technology deployment program for end users, policymakers, utilities, and industry stakeholders.

High electric rates in New England and the Middle Atlantic make these areas of the United States the most beneficial for cogeneration.<sup>[65][66]</sup>

5. [ISBN 978-0-8493-2274-7](#)

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#### [Electricity delivery](#)

##### Concepts

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- [Backfeeding](#)
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## Appearance

### Text

- 

☐ Small

☐ Standard

☐ Large

### Width

- 

☐ Standard

☐ Wide

### Color (beta)

-

☐ Automatic

☐ Light

☐ Dark

From Wikipedia, the free encyclopedia

This article is about accidental power failures. For intentionally engineered ones, see [rolling blackout](#). For other uses, see [Power Outage \(disambiguation\)](#).

"Power cut" redirects here. For the 2012 Punjabi film, see [Power Cut](#).



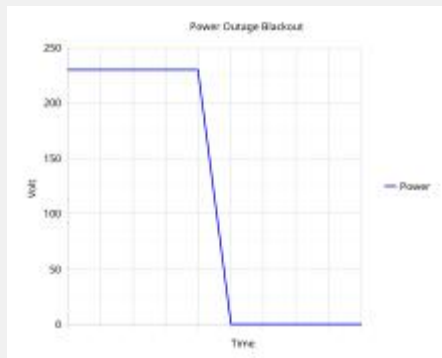
Vehicle lights provided the only illumination during the [2009 Ecuador electricity crisis](#).

A power outage, also called a powercut, a power out, a power failure, a power blackout, a power loss, a blackout or a power drought — is the loss of the [electrical power](#) network supply to an [end user](#).

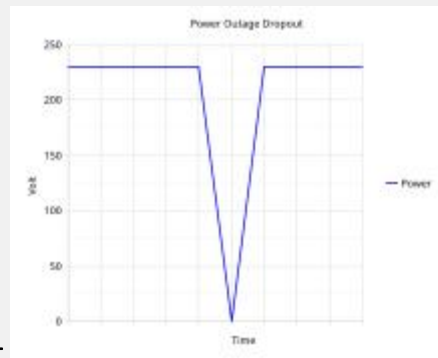
There are many causes of power failures in an electricity network. Examples of these causes include faults at [power stations](#), damage to [electric transmission lines](#), [substations](#) or other parts of the [distribution](#) system, a [short circuit](#), [cascading failure](#), [fuse](#) or [circuit breaker](#) operation.

Power failures are particularly critical at sites where the environment and public safety are at risk. Institutions such as [hospitals](#), [sewage treatment plants](#), and [mines](#) will usually have backup power sources such as [standby generators](#), which will automatically start up when electrical power is lost. Other critical systems, such as [telecommunication](#), are also required to have emergency power. The [battery room](#) of a telephone exchange usually has arrays of [lead–acid batteries](#) for backup and also a socket for connecting a generator during extended periods of outage. During a power outage, there is a disruption in the supply of electricity, resulting in a loss of power to homes, businesses, and other facilities. Power outages can occur for various reasons, including severe weather conditions (e.g. storms, hurricanes, or blizzards), earthquakes, equipment failure, grid overload, or planned maintenance.

## Types



Blackout



Transient fault

Power outages are categorized into three different phenomena, relating to the duration and effect of the outage:

- A transient fault is a loss of power typically caused by a fault on a power line, e.g. a [short circuit](#) or flashover. Power is automatically restored once the fault is cleared.
- A [brownout](#) is a drop in [voltage](#) in an electrical power supply. The term brownout comes from the dimming experienced by incandescent lighting when the voltage sags. Brownouts can cause poor performance of equipment or even incorrect operation.
- A blackout is the total loss of power to a wider area and of long duration.<sup>[1]</sup> It is the most severe form of power outage that can occur. Blackouts which result from or result in [power stations](#) tripping are particularly difficult to recover from quickly. Outages may last from a few minutes to a few weeks depending on the nature of the blackout and the configuration of the electrical network.

[Rolling blackouts](#) occur when demand for electricity exceeds supply, and allow some customers to receive power at the required voltage at the expense of other customers who get no power at all. They are a common occurrence in [developing countries](#), and may be scheduled in advance or occur without warning. They have also occurred in developed countries, for example in the [California electricity crisis](#) of 2000–2001, when government deregulation destabilized the wholesale electricity market. Blackouts are also used as a public safety measure, such as to prevent a [gas leak](#) from catching fire (for example, power was cut to several towns in response to the [Merrimack Valley gas explosions](#)), or to prevent wildfires around poorly maintained transmission lines (such as during the [2019 California power shutoffs](#)).

Protecting the power system from outages



Tree limbs creating a short circuit in power lines during a storm. This typically results in a power outage in the area supplied by these lines

In [power supply networks](#), the power generation and the electrical load (demand) must be very close to equal every second to avoid overloading of network components, which can severely damage them. [Protective relays](#) and [fuses](#) are used to automatically detect overloads and to disconnect circuits at risk of damage.

Under certain conditions, a network component shutting down can cause current fluctuations in neighboring segments of the network leading to a [cascading failure](#) of a larger section of the network. This may range from a building, to a block, to an entire city, to an entire [electrical grid](#).

Modern power systems are designed to be resistant to this sort of cascading failure, but it may be unavoidable (see below). Moreover, since there is no short-term economic benefit to preventing rare large-scale failures, researchers have expressed concern that there is a tendency to erode the resilience of the network over time, which is only corrected after a major failure occurs.<sup>[citation needed]</sup> In a 2003 publication, Carreras and co-authors claimed that reducing the likelihood of small outages only increases the likelihood of larger ones.<sup>[2]</sup> In that case, the short-term economic benefit of keeping the individual customer happy increases the likelihood of large-scale blackouts.

The [Senate Committee on Energy and Natural Resources](#) held a hearing in October 2018 to examine "[black start](#)", the process of restoring electricity after a system-wide power loss. The hearing's purpose was for Congress to learn about what the backup plans are in the electric utility industry in the case that the electric grid is damaged. Threats to the electrical grid include cyberattacks, solar storms, and severe weather, among others. For example, the "[Northeast Blackout of 2003](#)" was caused when overgrown trees touched high-voltage power lines. Around 55 million people in the U.S. and Canada lost power, and restoring it cost around \$6 billion.<sup>[3]</sup>

Protecting computer systems from power outages

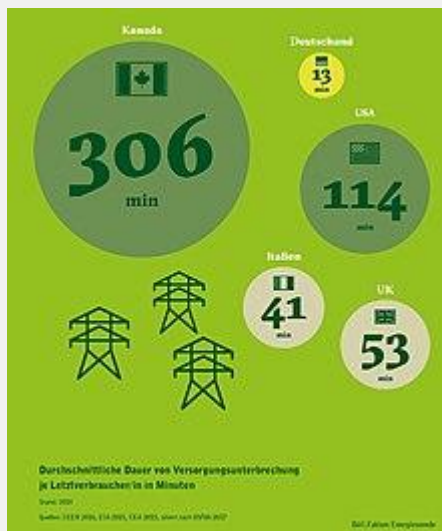
Computer systems and other electronic devices containing logic circuitry are susceptible to data loss or hardware damage that can be caused by the sudden loss of power. These can include data networking equipment, video projectors, alarm systems as well as computers. To protect computer systems against this, the use of an [uninterruptible power supply](#) or

'UPS' can provide a constant flow of electricity if a primary power supply becomes unavailable for a short period of time. To protect against surges (events where voltages increase for a few seconds), which can damage hardware when power is restored, a special device called a [surge protector](#) that absorbs the excess voltage can be used.

Restoring power after a wide-area outage

Restoring power after a wide-area outage can be difficult, as power stations need to be brought back online. Normally, this is done with the help of power from the rest of the grid. In the total absence of grid power, a so-called [black start](#) needs to be performed to [bootstrap](#) the power grid into operation. The means of doing so will depend greatly on local circumstances and operational policies, but typically [transmission](#) utilities will establish localized 'power islands' which are then progressively coupled together. To maintain supply frequencies within tolerable limits during this process, demand must be reconnected at the same pace that generation is restored, requiring close coordination between power stations, transmission and distribution organizations.

Blackout inevitability and electric sustainability



Comparison of duration of power outages ([SAIDI value](#)), in 2014.

Self-organized criticality

Further information: [Self-organized criticality control](#)

It has been argued on the basis of [historical data](#)<sup>[4]</sup> and computer modeling<sup>[5][6]</sup> that [power grids](#) are [self-organized critical systems](#). These systems exhibit unavoidable<sup>[7]</sup> disturbances of all sizes, up to the size of the entire system. This phenomenon has been attributed to steadily increasing demand/load, the economics of running a power company, and the

limits of modern engineering.<sup>[8]</sup>

While blackout frequency has been shown to be reduced by operating it further from its critical point, it generally is not economically feasible, causing providers to increase the average load over time or upgrade less often resulting in the grid moving itself closer to its critical point. Conversely, a system past the critical point will experience too many blackouts leading to system-wide upgrades moving it back below the critical point. The term critical point of the system is used here in the sense of statistical physics and nonlinear dynamics, representing the point where a system undergoes a [phase transition](#); in this case the transition from a steady reliable grid with few cascading failures to a very sporadic unreliable grid with common cascading failures. Near the critical point the relationship between blackout frequency and size follows a [power-law](#) distribution.<sup>[6][8]</sup>

[Cascading failure](#) becomes much more common close to this critical point. The [power-law](#) relationship is seen in both historical data and model systems.<sup>[8]</sup> The practice of operating these systems much closer to their maximum capacity leads to magnified effects of random, unavoidable disturbances due to aging, weather, human interaction etc. While near the critical point, these failures have a greater effect on the surrounding components due to individual components carrying a larger load. This results in the larger load from the failing component having to be redistributed in larger quantities across the system, making it more likely for additional components not directly affected by the disturbance to fail, igniting costly and dangerous cascading failures.<sup>[8]</sup> These initial disturbances causing blackouts are all the more unexpected and unavoidable due to actions of the power suppliers to prevent obvious disturbances (cutting back trees, separating lines in windy areas, replacing aging components etc.). The complexity of most power grids often makes the initial cause of a blackout extremely hard to identify.

Leaders are dismissive of system theories that conclude that blackouts are inevitable, but do agree that the basic operation of the grid must be changed. The [Electric Power Research Institute](#) champions the use of [smart grid](#) features such as power control devices employing [advanced sensors](#) to coordinate the grid.<sup>[9]</sup> Others advocate greater use of electronically controlled [high-voltage direct current](#) (HVDC) firebreaks to prevent disturbances from cascading across AC lines in a [wide area grid](#).<sup>[10]</sup>

OPA model

In 2002, researchers at [Oak Ridge National Laboratory](#) (ORNL), Power System Engineering Research Center of the [University of Wisconsin](#) (PSerc),<sup>[11]</sup> and the [University of Alaska Fairbanks](#) proposed a mathematical model for the behavior of electrical distribution systems.<sup>[12][13]</sup> This model has become known as the OPA model, a reference to the names of the authors' institutions. OPA is a cascading failure model. Other cascading failure models include Manchester, Hidden failure, CASCADE, and Branching.<sup>[14]</sup> The OPA model was quantitatively compared with a complex networks model of a [cascading failure](#) – Crucitti–Latora–Marchiori (CLM) model,<sup>[15]</sup> showing that both models exhibit similar phase

transitions in the average network damage (load shed/demand in OPA, path damage in CLM), with respect to transmission capacity.<sup>[16]</sup>

#### Mitigation of power outage frequency

The effects of trying to mitigate cascading failures near the critical point in an economically feasible fashion are often shown to not be beneficial and often even detrimental. Four mitigation methods have been tested using the *OPA* blackout model:<sup>[2]</sup>

- Increase critical number of failures causing cascading blackouts – Shown to decrease the frequency of smaller blackouts but increase that of larger blackouts.
- Increase individual power line max load – Shown to increase the frequency of smaller blackouts and decrease that of larger blackouts.
- Combination of increasing critical number and max load of lines – Shown to have no significant effect on either size of blackout. The resulting minor reduction in the frequency of blackouts is projected to not be worth the cost of the implementation.
- Increase the excess power available to the grid – Shown to decrease the frequency of smaller blackouts but increase that of larger blackouts.

In addition to the finding of each mitigation strategy having a cost-benefit relationship with regards to frequency of small and large blackouts, the total number of blackout events was not significantly reduced by any of the above-mentioned mitigation measures.<sup>[2]</sup>

A complex network-based model to control large [cascading failures](#) (blackouts) *using local information only* was proposed by A. E. Motter.<sup>[17]</sup>

In 2015, one of the solutions proposed to reduce the impact of power outage was introduced by M. S.

A smart meter is an [electronic](#) device that records information—such as consumption of [electric energy](#), voltage levels, current, and power factor—and [communicates the information](#) to the consumer and [electricity suppliers](#). Advanced metering infrastructure (AMI) differs from [automatic meter reading](#) (AMR) in that it enables two-way communication between the meter and the supplier.

#### Description

The term *smart meter* often refers to an [electricity meter](#), but it also may mean a device measuring [natural gas](#), [water](#) or [district heating](#) consumption.<sup>[1][2]</sup> More generally, a smart meter is an [electronic](#) device that records information such as consumption of [electric energy](#), voltage levels, current, and power factor. Smart meters [communicate the information](#) to the consumer for greater clarity of consumption behavior, and [electricity suppliers](#) for system monitoring and customer billing. Smart meters typically record energy near real-time, and report regularly, in short intervals throughout the day.<sup>[3]</sup> Smart meters

enable two-way communication between the meter and the central system. Smart meters may be part of a [smart grid](#), but do not themselves constitute a smart grid.<sup>[4]</sup>

Such an advanced metering infrastructure (AMI) differs from [automatic meter reading](#) (AMR) in that it enables two-way communication between the meter and the supplier. Communications from the meter to the network may be wireless, or via fixed wired connections such as [power line carrier \(PLC\)](#). Wireless communication options in common use include cellular communications, Wi-Fi (readily available), [wireless ad hoc networks](#) over Wi-Fi, [wireless mesh networks](#), [low power long-range wireless \(LoRa\)](#), [Wize](#) (high radio penetration rate, open, using the frequency 169 MHz) [Zigbee](#) (low power, low data rate wireless), and Wi-SUN (Smart Utility Networks).

Similar meters, usually referred to as [interval](#) or time-of-use meters, have existed for years, but smart meters usually involve real-time or near real-time sensors, [power outage](#) notification, and power quality monitoring. These additional features are more than simple [automated meter reading](#) (AMR). They are similar in many respects to [Advanced Metering Infrastructure](#) (AMI) meters. Interval and time-of-use meters historically have been installed to measure commercial and industrial customers, but may not have automatic reading.<sup>[citation needed]</sup> Research by the UK consumer group *Which?*, showed that as many as one in three confuse smart meters with [energy monitors](#), also known as in-home display monitors.<sup>[5][when?]</sup>

## History

In 1972, [Theodore Paraskevakos](#), while working with [Boeing](#) in [Huntsville, Alabama](#), developed a sensor monitoring system that used digital transmission for security, fire, and medical alarm systems as well as meter reading capabilities. This technology was a spin-off from the automatic telephone line identification system, now known as [Caller ID](#).

In 1974, Paraskevakos was awarded a U.S. patent for this technology.<sup>[6]</sup> In 1977, he launched Metretek, Inc.,<sup>[7]</sup> which developed and produced the first smart meters.<sup>[8]</sup> Since this system was developed pre-Internet, Metretek utilized the IBM series 1 mini-computer. For this approach, Paraskevakos and Metretek were awarded multiple patents.<sup>[9]</sup>

The installed base of smart meters in Europe at the end of 2008 was about 39 million units, according to analyst firm Berg Insight.<sup>[10]</sup> Globally, Pike Research found that smart meter shipments were 17.4 million units for the first quarter of 2011.<sup>[11]</sup> Visiongain determined that the value of the global smart meter market would reach [US\\$7 billion](#) in 2012.<sup>[12]</sup>

H.M. Zahid Iqbal, M. Waseem, and Dr. Tahir Mahmood, researchers of University of Engineering & Technology Taxila, Pakistan, introduced the concept of Smart Energy Meters in 2013. Their article, "Automatic Energy Meter Reading using Smart Energy Meter" outlined the key features of Smart Energy Meter including Automatic remote meter reading via GSM for utility companies and customers, Real-time monitoring of a customer's running load,

Remote disconnection and reconnection of customer connections by the utility company and Convenient billing, eliminating the need of meter readers to physically visit the customers for billing.

As of January 2018, over 99 million electricity meters were deployed across the European Union, with an estimated 24 million more to be installed by the end of 2020. The European Commission [DG Energy](#) estimates the 2020 installed base to have required €18.8 billion in investment, growing to €40.7 billion by 2030, with a total deployment of 266 million smart meters.<sup>[13]</sup>

By the end of 2018, the U.S. had over 86 million smart meters installed.<sup>[14]</sup> In 2017, there were 665 million smart meters installed globally.<sup>[15]</sup> Revenue generation is expected to grow from \$12.8 billion in 2017 to \$20 billion by 2022.<sup>[16]</sup>

#### Purpose

Since the inception of electricity [deregulation](#) and market-driven pricing throughout the world, utilities have been looking for a means to match consumption with generation. Non-smart electrical and gas meters only measure total consumption, providing no information of when the energy was consumed.<sup>[17]</sup> Smart meters provide a way of measuring electricity consumption in near real-time. This allows utility companies to charge different prices for consumption according to the time of day and the season.<sup>[18]</sup> It also facilitates more accurate cash-flow models for utilities. Since smart meters can be read remotely, labor costs are reduced for utilities.

Smart metering offers potential benefits to customers. These include, a) an end to estimated bills, which are a major source of complaints for many customers b) a tool to help consumers better manage their energy purchases—smart meters with a display outside their homes could provide up-to-date information on gas and electricity consumption and in doing so help people to manage their energy use and reduce their energy bills. With regards to consumption reduction, this is critical for understanding the benefits of smart meters because the relatively small percentage benefits in terms of savings are multiplied by millions of users.<sup>[19]</sup> Smart meters for water consumption can also provide detailed and timely information about customer water use and early notification of possible water leaks in their premises.<sup>[20]</sup> Electricity pricing usually peaks at certain predictable times of the day and the season. In particular, if generation is constrained, prices can rise if power from other jurisdictions or more costly generation is brought online. Proponents assert that billing customers at a higher rate for peak times encourages consumers to adjust their consumption habits to be more responsive to market prices and assert further, that regulatory and market design agencies hope these "[price signals](#)" could delay the construction of additional generation or at least the purchase of energy from higher-priced sources, thereby controlling the steady and rapid increase of electricity prices.<sup>[citation needed]</sup>

An academic study based on existing trials showed that homeowners' electricity

consumption on average is reduced by approximately 3-5% when provided with real-time feedback.<sup>[21]</sup>

Another advantage of smart meters that benefits both customers and the utility is the monitoring capability they provide for the whole electrical system. As part of an AMI, utilities can use the real-time data from smart meters measurements related to current, voltage, and power factor to detect system disruptions more quickly, allowing immediate corrective action to minimize customer impact such as blackouts. Smart meters also help utilities understand the power grid needs with more granularity than legacy meters. This greater understanding facilitates system planning to meet customer energy needs while reducing the likelihood of additional infrastructure investments, which eliminates unnecessary spending or energy cost increases.<sup>[22]</sup>

Though the task of meeting national electricity demand with accurate supply is becoming ever more challenging as intermittent renewable generation sources make up a greater proportion of the energy mix, the real-time data provided by smart meters allow grid operators to integrate renewable energy onto the grid in order to balance the networks. As a result, smart meters are considered an essential technology to the decarbonisation of the energy system.<sup>[23]</sup>

#### Advanced metering infrastructure

Advanced metering infrastructure (AMI) refers to systems that measure, collect, and analyze energy usage, and communicate with metering devices such as electricity meters, gas meters, heat meters, and water meters, either on request or on a schedule. These systems include hardware, software, communications, consumer energy displays and controllers, customer associated systems, [meter data management](#) software, and supplier business systems.

Government agencies and utilities are turning toward advanced metering infrastructure (AMI) systems as part of larger "smart grid" initiatives. AMI extends automatic meter reading (AMR) technology by providing two-way meter communications, allowing commands to be sent toward the home for multiple purposes, including [time-based pricing](#) information, [demand-response](#) actions, or remote service disconnects. Wireless technologies are critical elements of the neighborhood network, aggregating a mesh configuration of up to thousands of meters for back haul to the utility's IT headquarters.

The network between the measurement devices and business systems allows the collection and distribution of information to customers, suppliers, [utility companies](#), and service providers. This enables these businesses to participate in demand response services. Consumers can use the information provided by the system to change their normal consumption patterns to take advantage of lower prices. Pricing can be used to curb the growth of [peak demand](#) consumption. AMI differs from traditional [automatic meter reading](#) (AMR) in that it enables two-way communications with the meter. Systems only capable of

meter readings do not qualify as AMI systems.<sup>[24]</sup>



## Typical smart meter ami diagram

AMI implementation relies on four key components: Physical Layer Connectivity, which establishes connections between smart meters and networks, Communication Protocols to ensure secure and efficient data transmission, Server Infrastructure, which consists of centralized or distributed servers to store, process, and manage data for billing, monitoring, and demand response; and Data Analysis, where analytical tools provide insights, load forecasting, and anomaly detection for optimized energy management. Together, these components help utilities and consumers monitor and manage energy use efficiently, supporting smarter grid management.<sup>[25]</sup>

## Physical Layer Connectivity

Communication is a cornerstone of smart meter technology, enabling reliable and secure data transmission to central systems. However, the diversity of environments in which smart meters operate presents significant challenges. Solutions to these challenges encompass a range of communication methods<sup>[26]</sup> including [Power-line communication](#)<sup>[27]</sup> (PLC), [Cellular network](#),<sup>[28]</sup> [Wireless mesh network](#),<sup>[29]</sup> [Short-range](#),<sup>[29]</sup> and [satellite](#)<sup>[citation needed]</sup>.

- Power-line communication for Smart Metering

[Power Line Communication](#) (PLC)<sup>[a]</sup> stands out among smart metering connectivity technologies because it leverages existing electrical power infrastructure for data transmission. Unlike cellular, radio-frequency (RF), or Wi-Fi-based solutions, PLC does not require building or maintaining separate communication networks, making it inherently more cost-effective and easier to scale. Two major PLC standards in smart metering are G3-PLC and the [PRIME Alliance](#) protocol.<sup>[27]</sup> G3-PLC supports IPv6-based communications and adaptive data rates, providing robust performance even in noisy environments, while PRIME (Powerline Intelligent Metering Evolution) focuses on efficient, high-speed communication with low-cost implementation. PLC-based smart metering is deployed extensively in regions <sup>[30][31]</sup> like Europe, South America, and parts of Asia where dense infrastructure supports its use. Utilities favor PLC for its reliability in urban environments and for connecting large numbers of meters within smart grid networks.

An important feature of G3-PLC and PRIME is their ability to enable mesh networking (also called multi-hop), where smart meters act as repeaters for other meters in the network. This functionality allows meters to relay data from

neighboring meters to ensure that the information reaches the Data Concentrator Unit (DCU), even if direct communication is not possible due to distance or signal obstructions. This approach enhances network reliability and coverage, particularly in dense urban environments or geographically challenging areas.<sup>[32]</sup>

- Cellular Network ([GPRS](#), [NB-IoT](#), [LTE-M](#)): "Cellular technologies are highly scalable and secure. With national coverage, cellular connectivity can support a large number of meters in densely populated areas as well as reach those in remote locations."<sup>[28]</sup>
- Wireless mesh network (e.g. Wirepas<sup>[33]</sup> and Wi-Sun<sup>[34]</sup>): Ideal for urban areas, where devices can relay data to optimize coverage and reliability. It is mostly used for [Water Meter](#) and [Gas Meter](#)
- Short-range: such as Wireless M-Bus (WMBUS) are commonly used in smart metering applications to enable reliable, low-power communication between utility meters and local data collectors within buildings or neighborhoods.
- Hybrid PLC/RF PRIME and G3-PLC standards defines an integrated approach for seamless integration of PLC and wireless communication, enhancing reliability and flexibility in smart grids.<sup>[35]</sup>

Additional options, such as Wi-Fi<sup>[citation needed]</sup> and internet-based networks, are also in use. However, no single communication solution is universally optimal. The challenges faced by rural utilities differ significantly from those of urban counterparts or utilities in remote, mountainous, or poorly serviced areas.

Smart meters often extend their functionality through integration into Home Area Networks (HANs). These networks enable communication within the household and may include:

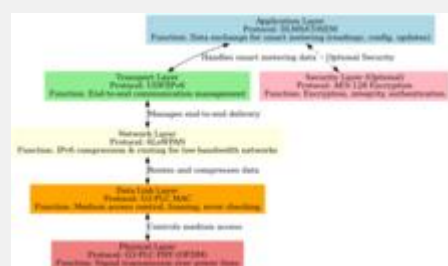
- In-Premises Displays: Providing real-time energy usage insights for consumers.
- Hubs: Interfacing multiple meters with the central head-end system.<sup>[citation needed]</sup>

Technologies used in HANs vary globally but typically include PLC, wireless ad hoc networks, and Zigbee. By leveraging appropriate connectivity solutions, smart meters can address diverse environmental and infrastructural needs while delivering seamless communication and enhanced functionality.<sup>[citation needed]</sup>

Smart meters used as a gateway for water and gas meters

Electricity smart meters start to be utilized as gateways for gas and water meters, creating integrated smart metering systems.<sup>[36]</sup> In this configuration, gas and water meters communicate with the electricity meter using Wireless M-Bus (Wireless Meter-Bus), a European standard (EN 13757-4) designed for secure and efficient data transmission between utility meters and data collectors. The electricity meter then aggregates this data and transmits it to the central utility network via Power Line Communication (PLC), which leverages existing electrical wiring for data transfer.

Smart meter communication protocols are essential for enabling reliable, efficient, and secure data exchange between meters, utilities, and other components of advanced metering infrastructure (AMI). These protocols address the diverse requirements of global markets, supporting various communication methods, from optical ports and serial connections to power line communication (PLC) and wireless networks. Below is an overview of key protocols, including ANSI standards widely used in North America, IEC protocols prevalent in Europe, the globally recognized OSGP for smart grid applications, and the PLC-focused Meters and More, each designed to meet specific needs in energy monitoring and management.



Typical communication stacks from Smart Meter to DC

- [IEC 62056](#)

"[IEC 62056](#) is the most widely adopted protocol"<sup>[37]</sup> for smart meter communication, enabling reliable, two-way data exchange within Advanced Metering Infrastructure (AMI) systems. It encompasses the DLMS/COSEM protocol for structuring and managing metering data. "It is widely used because of its flexibility, scalability, and ability to support different communication media such as Power Line Communication (PLC), TCP/IP, and wireless networks."<sup>[37]</sup> It also supports data transmission over serial connections using ASCII or binary formats, with physical media options such as modulated light (via LED and photodiode) or wired connections (typically EIA-485).<sup>[38]</sup>

- ANSI C12.18

ANSI C12.18 is an [ANSI](#) Standard that describes a [protocol](#) used for two-way communications with a meter, mostly used in North American markets. The C12.18 Standard is written specifically for meter communications via an ANSI Type 2 Optical Port, and specifies lower-level protocol details. [ANSI C12.19](#) specifies the data tables that are used. [ANSI C12.21](#) is an extension of C12.18 written for modem instead of optical communications, so it is better suited to [automatic meter reading](#). ANSI C12.22 is the communication protocol for remote communications.<sup>[39]</sup>

- OSGP

The [Open Smart Grid Protocol](#) (OSGP) is a family of specifications published by the [European](#)

[Telecommunications Standards Institute](#) (ETSI) used in conjunction with the ISO/IEC 14908 control networking standard for smart metering and smart grid applications. Millions of smart meters based on OSGP are deployed worldwide.<sup>[40]</sup> On July 15, 2015, the OSGP Alliance announced the release of a new security protocol (OSGP-AES-128-PSK) and its availability from OSGP vendors.<sup>[41]</sup> This deprecated the original OSGP-RC4-PSK security protocol which had been identified to be vulnerable.<sup>[42][43]</sup>

- Meters and More

"Meters and More was created in 2010 from the coordinated work between Enel and Endesa to adopt, maintain and evolve the field-proven Meters and More open communication protocol for smart grid solutions." <sup>[44]</sup> In 2010, the Meters and More Association was established to promote the protocol globally, ensuring interoperability and efficiency in power line communication (PLC)-based smart metering systems. Meters and More is an open communication protocol designed for advanced metering infrastructure (AMI). It facilitates reliable, high-speed data exchange over PLC networks, focusing on energy monitoring, demand response, and secure two-way communication between utilities and consumers. Unlike DLMS/COSEM, which is a globally standardized and versatile protocol supporting multiple utilities (electricity, gas, and water), Meters and More is tailored specifically for PLC-based systems, emphasizing efficiency, reliability, and ease of deployment in electricity metering.

There is a growing trend toward the use of [TCP/IP](#) technology as a common communication platform for Smart Meter applications, so that utilities can deploy multiple communication systems, while using IP technology as a common management platform.<sup>[45][46]</sup> A universal metering interface would allow for development and mass production of smart meters and smart grid devices prior to the communication standards being set, and then for the relevant communication modules to be easily added or switched when they are. This would lower the risk of investing in the wrong standard as well as permit a single product to be used globally even if regional communication standards vary.<sup>[47]</sup>

#### Server Infrastructure for Smart Meter AMI

In Advanced Metering Infrastructure (AMI), the server infrastructure is crucial for managing, storing, and processing the large volumes of data generated by smart meters. This infrastructure ensures seamless communication between smart meters, utility providers, and end-users, supporting real-time monitoring, billing, and grid management.

#### Key Components of AMI Server Infrastructure

##### Data Concentrator

A Data Concentrator Unit (DCU) aggregates data from multiple smart meters within a localized area (e.g., a neighborhood or building) before transmitting it to the central server. Data concentrators reduce the communication load on the network

and help overcome connectivity challenges by acting as intermediaries between smart meters and the head-end system (HES). They typically support communication protocols like IEC 62056, DLMS/COSEM<sup>[48]</sup>

#### Head-End System (HES)

The HES is responsible for collecting, validating, and managing data received from data concentrators and smart meters. It serves as the central communication hub, facilitating two-way communication between the smart meters and the utility's central servers. The HES supports meter configuration, firmware updates, and real-time data retrieval, ensuring data integrity and security.<sup>[49]</sup>

#### Meter Data Management System (MDMS)

The MDMS is a specialized software platform that stores and processes large volumes of meter data collected by the HES. Key functions of the MDMS include data validation, estimation, and editing, as well as billing preparation, load analysis, and anomaly detection. The MDMS integrates with other utility systems, such as billing, customer relationship management (CRM), and demand response systems, to enable efficient energy management.<sup>[50]</sup>

### Data Analytics

Data analytics for smart meters leverages machine learning to extract insights from energy consumption data. Key applications include demand forecasting, dynamic pricing, Energy Disaggregation, and fault detection, enabling optimized grid performance and personalized energy management. These techniques drive efficiency, cost savings, and sustainability in modern energy systems.

"Energy Disaggregation, or the breakdown of your energy use based on specific appliances or devices",<sup>[51]</sup> is an exploratory technique for analyzing energy consumption in households, commercial buildings, and industrial settings. By using data from a single energy meter, it employs algorithms and machine learning to estimate individual appliance usage without separate monitors. Known as Non-Intrusive Load Monitoring (NILM), this emerging method offers insights into energy efficiency, helping users optimize usage and reduce costs. While promising, energy disaggregation is still being refined for accuracy and scalability as part of smart energy management innovations.<sup>[52]</sup>

### Data management

The other critical technology for smart meter systems is the information technology at the utility that integrates the Smart Meter networks with utility applications, such as billing and CIS. This includes the Meter Data Management system.



This section may contain material [not related to the topic of the article](#). Please help [improve this section](#) or discuss this issue on the [talk page](#). (December 2024) ([Learn how and when to remove this message](#))

It also is essential for smart grid implementations that [power line communication](#) (PLC) technologies used within the home over a [Home Area Network](#) (HAN), are standardized and compatible. The HAN allows HVAC systems and other household appliances to communicate with the smart meter, and from there to the utility. Currently there are several broadband or narrowband standards in place, or being developed, that are not yet compatible. To address this issue, the National Institute for Standards and Technology ([NIST](#)) established the PAP15 group, which studies and recommends coexistence mechanisms with a focus on the harmonization of PLC Standards for the HAN. The objective of the group is to ensure that all PLC technologies selected for the HAN coexist as a minimum. The two leading broadband PLC technologies selected are the [HomePlug AV](#) / [IEEE 1901](#) and ITU-T [G.hn](#) technologies.<sup>[53]</sup> Technical working groups within these organizations are working to develop appropriate coexistence mechanisms. The [HomePlug Powerline Alliance](#) has developed a new standard for smart grid HAN communications called the [HomePlug Green PHY](#) specification. It is interoperable and coexistent with the widely deployed [HomePlug AV](#) technology and with the latest [IEEE 1901](#) global Standard and is based on Broadband [OFDM](#) technology. ITU-T commissioned in 2010 a new project called G.hnem, to address the home networking aspects of energy management, built upon existing Low Frequency Narrowband OFDM technologies.

#### Opposition and concerns

Some groups have expressed concerns regarding the cost, health, fire risk,<sup>[54]</sup> [security](#) and [privacy](#) effects of smart meters<sup>[55]</sup> and the remote controllable "[kill switch](#)" that is included with most of them. Many of these concerns regard wireless-only smart meters with no home energy monitoring or control or safety features. Metering-only solutions, while popular with utilities because they fit existing business models and have cheap up-front capital costs, often result in such "backlash". Often the entire [smart grid](#) and [smart building](#) concept is discredited in part by confusion about the difference between [home control](#) and [home area network](#) technology and AMI. The (now former) attorney general of Connecticut has stated that he does not believe smart meters provide any financial benefit to consumers,<sup>[56]</sup> however, the cost of the installation of the new system is absorbed by those customers.

#### Security

Smart meters expose the power grid to [cyberattacks](#) that could lead to [power outages](#), both by cutting off people's electricity<sup>[57]</sup> and by overloading the grid.<sup>[58]</sup> However many cyber security experts state that smart meters of UK and Germany have relatively high cybersecurity and that any such attack there would thus require extraordinarily high efforts or financial resources.<sup>[59][60][61]</sup> The EU Cyber security Act took effect in June 2019, which includes Directive on Security Network and Information Systems establishing notification and security requirements for [operators of essential services](#).<sup>[62]</sup>

Through the Smartgrid Cybersecurity Committee, the U.S. Department of Energy published cybersecurity guidelines for grid operators in 2010 and updated them in 2014. The guidelines "...present an analytical framework that organizations can use to develop effective cybersecurity strategies..."<sup>[63]</sup>

Implementing security protocols that protect these devices from malicious attacks has been problematic, due to their limited computational resources and long operational life.<sup>[64]</sup>

The current version of [IEC 62056](#) includes the possibility to encrypt, [authenticate](#), or [sign](#) the meter data.

One proposed smart meter data verification method involves analyzing the network traffic in real-time to detect anomalies using an [Intrusion Detection System](#) (IDS). By identifying exploits as they are being leveraged by attackers, an IDS mitigates the suppliers' risks of energy theft by consumers and denial-of-service attacks by hackers.<sup>[65]</sup> Energy utilities must choose between a centralized IDS, embedded IDS, or dedicated IDS depending on the individual needs of the utility. Researchers have found that for a typical advanced metering infrastructure, the centralized IDS architecture is superior in terms of cost efficiency and security gains.<sup>[64]</sup>

In the United Kingdom, the Data Communication Company, which transports the commands from the supplier to the smart meter, performs an additional anomaly check on commands issued (and signed) by the energy supplier.

As Smart Meter devices are Intelligent Measurement Devices which periodically record the measured values and send the data encrypted to the Service Provider, therefore in Switzerland these devices need to be evaluated by an evaluation Laboratory, and need to be certified by METAS from 01.01.2020 according to Prüfmethodologie (Test Methodology for Execution of Data Security Evaluation of Swiss Smart Metering Components).

According to a report published by [Brian Krebs](#), in 2009 a [Puerto Rico](#) electricity supplier asked the [FBI](#) to investigate large-scale thefts of electricity related to its smart meters. The FBI found that former employees of the power company and the company that made the meters were being paid by consumers to reprogram the devices to show incorrect results, as well as teaching people how to do it themselves.<sup>[66]</sup> Several hacking tools that allow security researchers and penetration testers verify the security of electric utility smart meters have been released so far.<sup>[67]</sup>

## Health

Most health concerns about the meters arise from the [pulsed radiofrequency](#) (RF) radiation emitted by wireless smart meters.<sup>[68]</sup>

Members of the California State Assembly asked the [California Council on Science and](#)

[Technology](#) (CCST) to study the issue of potential health impacts from smart meters, in particular whether current FCC standards are protective of public health.<sup>[69]</sup> The CCST report in April 2011 found no health impacts, based both on lack of scientific evidence of harmful effects from radio frequency (RF) waves and that the RF exposure of people in their homes to smart meters is likely to be minuscule compared to RF exposure to cell phones and microwave ovens.<sup>[70]</sup> Daniel Hirsch, retired director of the Program on Environmental and Nuclear Policy at [UC Santa Cruz](#), criticized the CCST report on the grounds that it did not consider studies that suggest the potential for non-thermal health effects such as latent cancers from RF exposure. Hirsch also stated that the CCST report failed to correct errors in its comparison to cell phones and microwave ovens and that, when these errors are corrected, smart meters "may produce cumulative whole-body exposures far higher than that of cell phones or microwave ovens."<sup>[71]</sup>

The Federal Communications Commission (FCC) has adopted recommended Permissible Exposure Limit (PEL) for all RF transmitters (including smart meters) operating at frequencies of 300 kHz to 100 GHz. These limits, based on field strength and power density, are below the levels of RF radiation that are hazardous to human health.<sup>[72]</sup>

Other studies substantiate the finding of the California Council on Science and Technology (CCST). In 2011, the [Electric Power Research Institute](#) performed a study to gauge human exposure to smart meters as compared to the FCC PEL. The report found that most smart meters only transmit RF signals 1% of the time or less. At this rate, and at a distance of 1 foot from the meter, RF exposure would be at a rate of 0.14% of the FCC PEL.<sup>[73]</sup>

An indirect potential for harm to health by smart meters is that they enable energy companies to disconnect consumers remotely, typically in response to difficulties with payment. This can cause health problems to vulnerable people in financial difficulty; in addition to denial of heat, lighting, and use of appliances, there are people who depend on power to use medical equipment essential for life. While there may be legal protections in place to protect the vulnerable, many people in the UK were disconnected in violation of the rules.<sup>[74]</sup>

## Safety

Issues surrounding smart meters causing fires have been reported, particularly involving the manufacturer Sensus. In 2012, [PECO Energy Company](#) replaced the Sensus meters it had deployed in the [Philadelphia](#), US region after reports that a number of the units had overheated and caused fires. In July 2014, [SaskPower](#), the province-run utility company of the Canadian province of [Saskatchewan](#), halted its roll-out of Sensus meters after similar, isolated incidents were discovered. Shortly afterward, [Portland General Electric](#) announced that it would replace 70,000 smart meters that had been deployed in the state of [Oregon](#) after similar reports. The company noted that it had been aware of the issues since at least 2013, and they were limited to specific models it had installed between 2010 and 2012.<sup>[75]</sup> On July 30, 2014, after a total of eight recent fire incidents involving the meters, SaskPower

was ordered by the [Government of Saskatchewan](#) to immediately end its smart meter program, and remove the 105,000 smart meters it had installed.<sup>[76]</sup>

#### Privacy concerns

One technical reason for privacy concerns is that these meters send detailed information about how much electricity is being used each time. More frequent reports provide more detailed information. Infrequent reports may be of little benefit for the provider, as it doesn't allow as good demand management in the response of changing needs for electricity. On the other hand, widespread reports would allow the utility company to infer [behavioral patterns](#) for the occupants of a house, such as when the members of the household are probably asleep or absent.<sup>[77]</sup> Furthermore, the fine-grained information collected by smart meters raises growing concerns of privacy invasion due to personal behavior exposure (private activity, daily routine, etc.).<sup>[20]</sup> Current trends are to increase the frequency of reports. A solution that benefits both provider and user privacy would be to adapt the interval dynamically.<sup>[78]</sup> Another solution involves energy storage installed at the household used to reshape the energy consumption profile.<sup>[79][80]</sup> In British Columbia the electric utility is government-owned and as such must comply with privacy laws that prevent the sale of data collected by smart meters; many parts of the world are serviced by private companies that are able to sell their data.<sup>[81]</sup> In Australia debt collectors can make use of the data to know when people are at home.<sup>[82]</sup> Used as evidence in a court case in [Austin, Texas](#), police agencies secretly collected smart meter power usage data from thousands of residences to determine which used more power than "typical" to identify marijuana growing operations.<sup>[83]</sup>

Smart meter power data usage patterns can reveal much more than how much power is being used. Research has demonstrated that smart meters sampling power levels at two-second intervals can reliably identify when different electrical devices are in use.<sup>[84][85][86][87][88][89][90][91]</sup>

Ross Anderson wrote about privacy concerns "It is not necessary for my meter to tell the power company, let alone the government, how much I used in every half-hour period last month"; that meters can provide "targeting information for burglars"; that detailed energy usage history can help energy companies to sell users exploitative contracts; and that there may be "a temptation for policymakers to use smart metering data to target any needed power cuts."<sup>[92]</sup>

#### Opt-out options

Reviews of smart meter programs, moratoriums, delays, and "opt-out" programs are some responses to the concerns of customers and government officials. In response to residents who did not want a smart meter, in June 2012 a utility in Hawaii changed its smart meter program to "opt out".<sup>[93]</sup> The utility said that once the smart grid installation project is nearing completion, KIUC may convert the deferral policy to an opt-out policy or program

and may charge a fee to those members to cover the costs of servicing the traditional meters. Any fee would require approval from the Hawaii Public Utilities Commission.

After receiving numerous complaints about health, hacking, and privacy concerns with the wireless digital devices, the Public Utility Commission of the [US](#) state of [Maine](#) voted to allow customers to opt-out of the meter change at the cost of \$12 a month.<sup>[94]</sup> In [Connecticut](#), another US state to consider smart metering, regulators declined a request by the state's largest utility, [Connecticut Light & Power](#), to install 1.2 million of the devices, arguing that the potential savings in electric bills do not justify the cost. CL&P already offers its customers time-based rates. The state's Attorney General [George Jepsen](#) was quoted as saying the proposal would cause customers to spend upwards of \$500 million on meters and get few benefits in return, a claim that Connecticut Light & Power disputed.<sup>[95]</sup>

#### Abuse of dynamic pricing

Smart meters allow dynamic pricing; it has been pointed out that, while this allows prices to be reduced at times of low demand, it can also be used to increase prices at peak times if all consumers have smart meters.<sup>[96]</sup> Additionally smart meters allow energy suppliers to switch customers to expensive prepay tariffs instantly in case of difficulties paying. In the UK during a period of very high energy prices from 2022, companies were remotely switching smart meters from a credit tariff to an expensive prepay tariff which disconnects supplies unless credit has been purchased. While regulations do not permit this without appropriate precautions to help those in financial difficulties and to protect the vulnerable, the rules were often flouted.<sup>[74]</sup> (Prepaid tariffs could also be levied without smart meters, but this required a dedicated prepay meter to be installed.) In 2022, 3.2 million people were left without power at some point after running out of prepay credit.<sup>[97]</sup>

#### Limited benefits

There are questions about whether electricity is or should be primarily a "when you need it" service where the inconvenience/[cost-benefit](#) ratio of time-shifting of loads is poor. In the Chicago area, Commonwealth Edison ran a test installing smart meters on 8,000 randomly selected households together with variable rates and rebates to encourage cutting back during peak usage.<sup>[98]</sup> In *Crain's Chicago Business* article "Smart grid test underwhelms. In the pilot, few power down to save money.", it was reported that fewer than 9% exhibited any amount of peak usage reduction and that the overall amount of reduction was "statistically insignificant".<sup>[98]</sup> This was from a report by the Electric Power Research Institute, a utility industry think tank who conducted the study and prepared the report. Susan Satter, senior assistant Illinois attorney general for public utilities said "It's devastating to their plan.....The report shows zero statistically different result compared to business as usual." <sup>[98]</sup>

By 2016, the 7 million smart meters in Texas had not persuaded many people to check their

energy data as the process was too complicated.<sup>[99]</sup>

A report from a parliamentary group in the UK suggests people who have smart meters installed are expected to save an average of £11 annually on their energy bills, much less than originally hoped.<sup>[100]</sup> The 2016 cost-benefit analysis was updated in 2019 and estimated a similar average saving.<sup>[101]</sup>

The Australian Victorian Auditor-General found in 2015 that 'Victoria's electricity consumers will have paid an estimated \$2.239 billion for metering services, including the rollout and connection of smart meters. In contrast, while a few benefits have accrued to consumers, benefits realisation is behind schedule and most benefits are yet to be realised'<sup>[102]</sup>

#### Erratic demand

Smart meters can allow real-time pricing, and in theory this could help smooth power consumption as consumers adjust their demand in response to price changes. However, modelling by researchers at the University of Bremen suggests that in certain circumstances, "power demand fluctuations are not dampened but amplified instead."<sup>[103]</sup>

#### In the media

In 2013, *Take Back Your Power*, an independent Canadian documentary directed by Josh del Sol was released describing "dirty electricity" and the aforementioned issues with smart meters.<sup>[104]</sup> The film explores the various contexts of the health, legal, and economic concerns. It features narration from the [mayor of Peterborough, Ontario, Daryl Bennett](#), as well as American researcher De-Kun Li, journalist Blake Levitt,<sup>[105]</sup> and Dr. Sam Milham. It won a [Leo Award](#) for best feature-length documentary and the Annual Humanitarian Award from Indie Fest the following year.

#### UK roll-out criticism

In a 2011 submission to the Public Accounts Committee, [Ross Anderson](#) wrote that Ofgem was "making all the classic mistakes which have been known for years to lead to public-sector IT project failures" and that the "most critical part of the project—how smart meters will talk to domestic appliances to facilitate demand response—is essentially ignored."<sup>[106]</sup>

[Citizens Advice](#) said in August 2018 that 80% of people with smart meters were happy with them. Still, it had 3,000 calls in 2017 about problems. These related to first-generation smart meters losing their functionality, aggressive sales practices, and still having to send smart meter readings.<sup>[107]</sup>

Ross Anderson of the Foundation for Information Policy Research has criticised the UK's program on the grounds that it is unlikely to lower energy consumption, is rushed and expensive, and does not promote metering competition. Anderson writes, "the proposed

architecture ensures continued dominance of metering by energy industry incumbents whose financial interests are in selling more energy rather than less," and urged ministers "to kill the project and instead promote competition in domestic energy metering, as the Germans do – and as the UK already has in industrial metering. Every consumer should have the right to appoint the meter operator of their choice."<sup>[108]</sup>

The high number of SMETS1 meters installed has been criticized by Peter Earl, head of energy at the price comparison website comparethemarket.com. He said, "The Government expected there would only be a small number of the first-generation of smart meters before Smets II came in, but the reality is there are now at least five million and perhaps as many as 10 million Smets I meters."<sup>[109]</sup>

UK smart meters in southern England and the Midlands use the mobile phone network to communicate, so they do not work correctly when phone coverage is weak. A solution has been proposed, but was not operational as of March 2017.<sup>[109]</sup>

In March 2018 the [National Audit Office](#) (NAO), which watches over public spending, opened an investigation into the smart meter program, which had cost £11bn by then, paid for by electricity users through higher bills.<sup>[110][111]</sup> The National Audit Office published the findings of its investigation in a report titled "Rolling out smart meters" published in November 2018.<sup>[112]</sup> The report, amongst other findings, indicated that the number of smart meters installed in the UK would fall materially short of the Department for Business, Energy & Industrial Strategy (BEIS) original ambitions of all UK consumers having a smart meter installed by 2020. In September 2019, smart meter rollout in the UK was delayed for four years.<sup>[113]</sup>

Ross Anderson and Alex Henney wrote that "[Ed Miliband](#) cooked the books" to make a case for smart meters appear economically viable. They say that the first three cost-benefit analyses of residential smart meters found that it would cost more than it would save, but "ministers kept on trying until they got a positive result... To achieve 'profitability' the previous government stretched the assumptions shamelessly".<sup>[114]</sup>

A counter-fraud officer at [Ofgem](#) with oversight of the roll-out of the smart meter program who raised concerns with his manager about many millions of pounds being misspent was threatened in 2018 with imprisonment under section 105 of the [Utilities Act 2000](#), prohibiting disclosure of some information relevant to the energy sector, with the intention of protecting national security.<sup>[115][116]</sup> The [Employment Appeal Tribunal](#) found that the law was in contravention of the [European Convention on Human Rights](#).<sup>[117]</sup>

Main Suppliers

Top ten smart electricity meters suppliers depends on the ranking method<sup>[118]</sup>

Among them

- [Landis+Gyr](#)
- [Itron](#)
- [Xylem](#) (formerly Sensus)
- [Sagemcom](#) <sup>[fr]</sup>
- [Honeywell](#) / Elster
  
- [Kamstrup A/S](#) <sup>[da]</sup>
- [Wasion Holdings Limited](#) <sup>[zh]</sup>
- Holley Technology Ltd

Gallery



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Newer retrofitted U.S. domestic digital electricity meter Elster REX<sup>[119]</sup> with 900 MHz<sup>[120]</sup> [mesh network](#) topology for [automatic meter reading](#) and "EnergyAxis" time-of-use metering. <sup>[121][122][123]</sup>



•

Each local mesh networked smart meter has a hub such as this Elster A3 Type A30, which interfaces 900MHz smart meters to the metering automation server via a landline. <sup>[124]</sup>



•

Ittron OpenWay electricity Smart meter with two-way communications for remote reading in use by [DTE Energy](#)

om Wikipedia, the free encyclopedia  
(Redirected from [Electric energy](#))

Electrical energy is the [energy](#) transferred as electric charges move between points with different [electric potential](#), that is, as they move across a [potential difference](#). As electric potential is lost or gained, work is done changing the energy of some system. The amount of work in [joules](#) is given by the product of the charge that has moved, in [coulombs](#), and the potential difference that has been crossed, in [volts](#).<sup>[1]</sup>

Electrical energy is usually sold by the [kilowatt hour](#) (1 kW·h = 3.6 MJ) which is the product of the power in kilowatts multiplied by running time in hours. Electric utilities measure energy using an [electricity meter](#), which keeps a running total of the electrical energy delivered to a customer.

[Electric heating](#) is an example of converting electrical energy into [thermal energy](#). The simplest and most common type of electric heater uses [electrical resistance](#) to convert the energy. There are other ways to use electrical energy. Electric charges moves as a current the heater element which has a potential difference between the ends: energy is transferred from the charges to the element, increasing the element's temperature and thermal energy as the charges lose potential energy.

Electricity generation

Main article: [Electricity generation](#)

Electricity generation is the process of generating electrical energy from other [forms of energy](#).

The fundamental principle of electricity generation was discovered during the 1820s and early 1830s by the British scientist [Michael Faraday](#). His basic method is still used today: electric current is generated by the movement of a loop of wire, or [disc of copper](#) between the poles of a [magnet](#).<sup>[2]</sup>

For electrical utilities, it is the first step in the delivery of electricity to consumers. The other processes, electricity [transmission](#), [distribution](#), and electrical energy storage and recovery using [pumped-storage](#) methods are normally carried out by the [electric power industry](#).<sup>[3]</sup>

Electricity is most often generated at a [power station](#) by electromechanical [generators](#), primarily driven by [heat engines](#) fueled by chemical [combustion](#) or [nuclear fission](#) but also by other means such as the [kinetic energy](#) of flowing water and wind. There are

M-Bus or Meter-Bus is a [European standard](#) (EN 13757-2 physical and link layer, EN 13757-3 application layer) for the remote reading of [water](#), [gas](#) or [electricity meters](#). M-Bus is also usable for other types of consumption meters, such as heating systems or [water meters](#). The M-Bus interface is made for communication on two wires, making it cost-effective. A radio variant of M-Bus Wireless M-Bus is also specified in EN 13757-4.

The M-Bus was developed to fill the need for a system for the networking and remote reading of utility meters, for example to measure the consumption of gas or water in the home. This bus fulfills the special requirements of remotely powered or battery-driven systems, including consumer utility meters. When interrogated, the meters deliver the data they have collected to a common master, such as a hand-held computer, connected at periodic intervals to read all utility meters of a building. An alternative method of collecting data centrally is to transmit meter readings via a [modem](#).

Other applications for the M-Bus such as alarm systems, flexible illumination installations, heating control, etc. are suitable.

Relation to the OSI model

Since no bus system was available for the requirements of meter reading, the M-Bus was developed by [Horst Ziegler](#) of the [University of Paderborn](#) in cooperation with [Texas Instruments Deutschland GmbH](#) and [Techem GmbH \[de\]](#). The concept was based on the [ISO-OSI Reference Model](#), in order to realize an open system which could use almost any desired protocol.

Since the M-Bus is not a network, and therefore does not - among other things - need a transport or session layer, the levels four to six of the OSI model are empty. Therefore, only the physical, the data link, the network and the application layer are provided with functions.

OSI Model			
	Data unit	Layer	Standard
Host layers	Data	7. <a href="#">Application</a>	EN1434-3
		6. <a href="#">Presentation</a>	Empty
		5. <a href="#">Session</a>	Empty
	Segment/Datagram	4. <a href="#">Transport</a>	Empty
Media layers	Packet	3. <a href="#">Network</a>	Optional
	Frame	2. <a href="#">Data link</a>	<a href="#">IEC 60870</a>
	Bit	1. <a href="#">Physical</a>	M-Bus

Physical wire and connectors

M-Bus connection is called M-Bus or HAN (Home Area Network) consumer connection. M-Bus uses two-wire telephone cable (JYStY 1x2x0.8 mm or similar, 73 ohm/km, 120 nF/km)

maximum length of 350 meters when using nominal transfer speeds 300 and 9600 baud. Lowering the speed up to 1000 meter cable can be used. There is no standardized connector, but RJ11 and RJ12 [Modular connectors](#) are used by meter manufacturers.<sup>[1]</sup>

The master communication uses voltage signaling, where 1 (idle state, mark) is the bus nominal 36 volts, 0 (space) drops the voltage to 24 volts. As bus voltage can vary with length and load, the signal is specified as 1 for bus voltage drop less than 5.5V, 0 for drop higher than 8.2 volts.

Slaves communicate by [current consumption](#), where 1 (idle state, mark) is less than 1.5 milliamperes, 0 (space) raises current to 11-20 mA. The signal is specified as the at least 11 mA current increase.

The slaves are connected via [diode bridge](#) and can use either polarity of the wires. To protect the bus against shortcircuited slaves, a 430 ohm is connected in series at each slave (or, two 215 ohm resistors, one for each wire).

A M-bus load unit is 1.5 mA. Most slaves use at most this, some can need two units (3 mA). Masters can provide type-dependent number of load units, and usually visually indicate overload.

Data link protocol

The data link protocol is described by IEC 870-5, or its updated version, [IEC 60870-5](#).

The data are sent in serial form, at speed between 300 and 9600 bit/s (some variants may operate up to 19200 or 38400 bit/s), using one start bit, one stop bit, and [even parity](#) (8e1). The [least significant bit](#) is sent first. When sending packets ("telegrams"), there is no pause between stop and subsequent start bit.

Suggested speeds are 300, 2400, 9600, and with newer hardware 38400 bit/s, while 2400 bit/s is most common. Devices with different [baudrates](#) can coexist on the same bus. Some devices use [autobauding](#)<sup>[clarification needed]</sup>.

There are four kinds of packets:

- single character - 0xE5 - acknowledgement
- short frame, 5 bytes - 0x10, C-field, A-field, checksum, 0x16 - sending simple commands
- control frame, 9 bytes - 0x68, 0x03, 0x03, 0x68, C-field, A-field, CI-field, checksum, 0x16
  - The control frame is a long frame with no payload.
- long frame, 9+ bytes - 0x68, length, length, 0x68, C-field, A-field, CI-field, [0..252

payload bytes], checksum, 0x16

C-field is the control/function field. The sequence, from bit 7, is:

- bit 7: 0
- bit 6: 1 for master-to-slave, 0 for slave reply
- bit 5:
  - from master: FCB, frame count bit - indicates request to repeat message when reply was not received
  - from slave: ACD, access demand - 1 when slave wishes to transmit class-1 data, priority data (class-2 data is ordinary non-priority) - the master then should request the class-1 data transfer
- bit 4:
  - from master: FCV, frame count valid - when 0, slave should ignore FCB
  - from slave: DFC, data flow control - when 1, slave can not accept further data
- bit 3,2,1,0: F3,F2,F1,F0, function code - eg. for short frame, 0 is for initialization of slave, xA is for class-1 (priority) data read, xB is for class-2 (normal) read. For long/control frame, x3 is sending data to slave, x8 is data reply from slave.

A-field is the address field. It is a 8-bit number:

- 0x00 - unset address, assigned at manufacture time, some meters fixed at this
- 0x01..0xFA - slave addresses
- 0xFB, 0xFC - reserved
- 0xFD - "broadcast" for secondary addressing, addressing done on network layer instead of on data link layer
- 0xFE - test broadcast, all slaves reply (collisions will happen, use for testing with a single slave; slave replies with its own address in A-field), also possible to use when there is only one slave on the bus
- 0xFF - broadcast, no reply from slaves

CI-field is the control information field. Defined at application layer.<sup>[2]</sup>

Length field in control/long frame is sent twice. Both bytes have to be equal. Minimum value is 0x03, as C-field, A-field and CI-field are mandatory parts of the payload.

Slaves respond only to correctly formed packets that match their address. Any fault is indicated by lack of response. Absence of response is defined as no response for 330 bit periods (35 ms for 9600 bit/s, 1.1 s for 300 bit/s) plus 50 ms.<sup>[3]</sup>

Numerical values are usually sent in [BCD](#) format.<sup>[4]</sup>

Electric energy consumption is [energy consumption](#) in the form of [electrical energy](#).<sup>[2]</sup> About a fifth of global energy is consumed as electricity: for residential, industrial, commercial,

[transportation](#) and other purposes.<sup>[2]</sup> The global electricity consumption in 2022 was 24,398 [terawatt-hour](#) (TWh), almost exactly three times the amount of consumption in 1981 (8,132 TWh).<sup>[3]</sup><sup>[failed verification]</sup> China, the United States, and India accounted for more than half of the global share of electricity consumption. Japan and Russia followed with nearly twice the consumption of the remaining industrialized countries.<sup>[3]</sup>

## Overview

Electric energy is most often measured either in [joules](#) (J), or in watt hours (W·h).<sup>[4]</sup>

$$1 \text{ W} \cdot \text{s} = 1 \text{ J}$$

$$1 \text{ W} \cdot \text{h} = 3,600 \text{ W} \cdot \text{s} = 3,600 \text{ J}$$

$$1 \text{ kWh} = 3,600 \text{ kWs} = 1,000 \text{ Wh} = 3.6 \text{ million W} \cdot \text{s} = 3.6 \text{ million J}$$

Electric and electronic devices consume electric energy to generate desired output (light, heat, motion, etc.). During operation, some part of the energy is lost depending on the [electrical efficiency](#).<sup>[5]</sup>

Electricity has been generated in power stations since 1882.<sup>[6]</sup> The invention of the steam turbine in 1884 to drive the electric generator led to an increase in worldwide electricity consumption.<sup>[7]</sup>

In 2022, the total worldwide electricity production was nearly 29,000 TWh.<sup>[8]</sup> Total [primary energy](#) is converted into numerous forms, including, but not limited to, electricity, heat and motion.<sup>[9]</sup> Some primary energy is lost during the conversion to electricity, as seen in the United States, where a little more than 60% was lost in 2022.<sup>[9]</sup>

Electricity accounted for more than 20% of worldwide final energy consumption in 2022, with oil being less than 40%, coal being less than 9%, natural gas being less than 15%, biofuels and waste less than 10%, and other sources (such as heat, solar electricity, wind electricity and geothermal) being more than 5%.<sup>[10]</sup> The total final electricity consumption in 2022 was split unevenly between the following sectors: industry (42.2%), residential (26.8%), commercial and public services (21.1%), transport (1.8%), and other (8.1%; i.e., agriculture and fishing).<sup>[10]</sup> In 1981, the final electricity consumption continued to decrease in the industrial sector and increase in the residential, commercial and public services sectors.<sup>[10]</sup>

A sensitivity analysis on an adaptive neuro-fuzzy network model for electric demand estimation shows that employment is the most critical factor influencing electrical consumption.<sup>[11]</sup> The study used six parameters as input data, employment, [GDP](#), dwelling, population, [heating degree day](#) and [cooling degree day](#), with electricity demand as output variable.<sup>[11]</sup>

## World electricity consumption

See also: [List of countries by electricity consumption](#)

The table lists 45 electricity-consuming countries, which used about 22,000 TWh. These countries comprise about 90% of the final consumption of 190+ countries. The final consumption to generate this electricity is provided for every country. The data is from 2022.<sup>[8][12]</sup>

In 2022, OECD's final electricity consumption was over 10,000 TWh.<sup>[3]</sup> In that year, the industrial sector consumed about 42.2% of the electricity, with the residential sector consuming nearly 26.8%, the commercial and public services sectors consuming about 21.1%, the transport sector consuming nearly 1.8%, and the other sectors (such as agriculture and fishing) consuming nearly 8.1%.<sup>[10]</sup> In recent decades, the consumption in the residential and commercial and public services sectors has grown, while the industry consumption has declined.<sup>[3]</sup> More recently, the transport sector has witnessed an increase in consumption with the growth in the [electric vehicle](#) market.<sup>[3]</sup>

Electricity consumption of selected countries (OECD, 2022)<sup>[8][12]</sup>

Rank	Country	Final consumption (TWh)	Population (millions)	<a href="#">Per capita</a> consumption (MWh)
—	<b>WORLD</b>	24,398	7,960	3.07
1	 <a href="#">China</a>	7,214	1,443	5
2	 <a href="#">United States</a>	4,272	336	12.71
3	 <a href="#">India</a>	1,403	1,401	1
4	 <a href="#">Japan</a>	1,132	126	8.98
5	 <a href="#">Russia</a>	934	146	6.4
6	 <a href="#">Canada</a>	595	38.1	15.62
7	 <a href="#">South Korea</a>	553	51.2	10.8
8	 <a href="#">Brazil</a>	550	215	2.56
9	 <a href="#">Germany</a>	539	82.2	6.55
10	 <a href="#">France</a>	463	67.7	6.84
11	 <a href="#">Saudi Arabia</a>	317	36	8.81
12	 <a href="#">United Kingdom</a>	312	68.4	4.56
13	 <a href="#">Indonesia</a>	308	276	1.17
14	 <a href="#">Italy</a>	300	60	5
15	 <a href="#">Mexico</a>	296	127	2.33
16	 <a href="#">Iran</a>	280	83.3	3.36
17	 <a href="#">Turkey</a>	264	84	3.14

18	 <a href="#">Taiwan</a>	257	23.8 <sup>[13]</sup>	10.8
19	 <a href="#">Spain</a>	246	46.8	5.26
20	 <a href="#">South Africa</a>	233	60	3.88
21	 <a href="#">Australia</a>	225	26	8.65
22	 <a href="#">Vietnam</a>	220	100	2.2
23	 <a href="#">Thailand</a>	203	70	2.9
24	 <a href="#">Malaysia</a>	170	33.2	5.12
25	 <a href="#">Egypt</a>	168	105	1.6
26	 <a href="#">Poland</a>	156	37.5	4.17
27	 <a href="#">Ukraine</a>	154	43.2	3.56
28	 <a href="#">Sweden</a>	147	10.2	14.4
29	 <a href="#">Argentina</a>	138	46	3
30	 <a href="#">United Arab Emirates</a>	136	10.2	13.33
31	 <a href="#">Norway</a>	128	5.5	23.27
32	 <a href="#">Pakistan</a>	124	226	0.55
33	 <a href="#">Netherlands</a>	120	17.5	6.86
34	 <a href="#">Belgium</a>	98	11.8	8.33
35	 <a href="#">Finland</a>	90	5.6	16.03
36	 <a href="#">Chile</a>	84	19.2	4.38
37	 <a href="#">Kazakhstan</a>	75	18.7	4
38	 <a href="#">Austria</a>	73	9.1	8.02
39	 <a href="#">Venezuela</a>	72	28.1	2.56
40	 <a href="#">Algeria</a>	66	44	1.5
41	 <a href="#">Switzerland</a>	62	9.3	6.67
42	 <a href="#">Israel</a>	59	9.4	6.27
43	 <a href="#">New Zealand</a>	43	5	8.6
44	 <a href="#">Denmark</a>	35	5.8	6.02
45	 <a href="#">Ireland</a>	28	5.5	5.1

Consumption per capita

The final consumption divided by the number of inhabitants provides a country's consumption per capita. In Western Europe, this is between 4 and 8 MWh/year.<sup>[8]</sup> (1 MWh = 1,000 kWh) In Scandinavia, the United States, Canada, Taiwan, South Korea, Australia, Japan and the United Kingdom, the per capita consumption is higher; however, in developing countries, it is much lower.<sup>[8]</sup> The world's average was about 3 MWh/year in 2022.<sup>[8]</sup> Very low consumption levels, such as those in [Philippines](#), not included in the table, indicate that

many inhabitants are not connected to the electricity grid, and that is the reason why some of the world's most populous countries, including [Nigeria](#) and [Bangladesh](#), do not appear in the table.<sup>[12]</sup>

#### Electricity generation and GDP

The table lists 30 countries, which represent about 76% of the world population, 84% of the world GDP, and 85% of the world electricity generation.<sup>[8][12][14][15]</sup> Productivity per electricity generation (concept similar to [energy intensity](#)) can be measured by dividing GDP over the electricity generated. The data is from 2019.<sup>[8][12][14][15]</sup>

Electricity generation (2019) and GDP (PPP) (2019)									
Country	Population, millions	rank *	GDP (PPP), billions (USD)	rank *	GDP (PPP) per capita	rank *	Electricity generation (GWh/yr)	rank *	GDP (PPP) /kWh *
 <a href="#">China</a>	1,407	1	\$14,280	2	\$10,149	15	7,503,428	1	\$1.9
 <a href="#">India</a>	1,366	2	\$2,871	6	\$2,102	26	1,603,675	3	\$1.8
 <a href="#">USA</a>	328	3	\$21,433	1	\$65,345	1	4,411,159	2	\$4.9
 <a href="#">Indonesia</a>	270.6	4	\$1,119	16	\$4,135	20	278,942	17	\$4.0
 <a href="#">Brazil</a>	211	6	\$1,878	9	\$8,900	18	626,328	7	\$3.0
 <a href="#">Pakistan</a>	216.6	5	\$279	26	\$1,288	28	138,626	24	\$2.0
 <a href="#">Bangladesh</a>	163	8	\$302	25	\$1,853	27	89,672	27	\$3.4
 <a href="#">Nigeria</a>	201	7	\$448	22	\$2,229	25	33,552 <sup>[16]</sup>	28	\$13.4
 <a href="#">Russia</a>	144	9	\$1,687	11	\$11,715	14	1,118,143	4	\$1.5
 <a href="#">Japan</a>	126	11	\$5,149	3	\$40,865	7	1,030,286	5	\$5.0
 <a href="#">Mexico</a>	127.6	10	\$1,269	15	\$9,945	16	322,584	13	\$3.9
 <a href="#">Philippines</a>	108	13	\$377	23	\$3,491	21	106,041	26	\$3.6
 <a href="#">Vietnam</a>	96.5	15	\$262	27	\$2,715	24	227,461	21	\$1.2
 <a href="#">Ethiopia</a>	112	12	\$96	29	\$857	29	14,553 <sup>[17]</sup>	29	\$6.6
















<a href="#"> Egypt</a>	100.4	14	\$303	24	\$3,018	23	200,563	22	\$1.5
<a href="#"> Germ</a>	83	18	\$3,888	4	\$46,843	4	609,406	8	\$6.4
<a href="#"> Turke</a>	83.5	17	\$761	19	\$9,114	17	303,898	15	\$2.5
<a href="#"> DR Congo</a>	86.8	16	\$50	30	\$576	30	9,990 <sup>[18]</sup>	30	\$5.0
<a href="#"> Iran</a>	83	19	\$258	28	\$3,108	22	318,696	14	\$0.8
<a href="#"> Thaila</a>	69.6	20	\$544	21	\$7,816	19	186,503	23	\$2.9
<a href="#"> Franc</a>	67.3	21	\$2,729	7	\$40,550	8	562,842	10	\$4.8
<a href="#"> UK</a>	66.8	22	\$2,879	5	\$43,099	6	324,761	12	\$8.9
<a href="#"> Italy</a>	59.7	23	\$2,009	8	\$33,652	9	293,853	16	\$6.8
<a href="#"> South Korea</a>	51.7	24	\$1,651	12	\$31,934	10	585,301	9	\$2.8
<a href="#"> Spain</a>	47.1	25	\$1,393	13	\$29,575	11	267,501	19	\$5.2
<a href="#"> Canad</a>	37.6	26	\$1,742	10	\$46,330	5	648,676	6	\$2.7
<a href="#"> Saudi Arabia</a>	34.3	27	\$793	18	\$23,120	13	343,661	11	\$2.3
<a href="#"> Taiwa</a>	23.6 <sup>[13]</sup>	28	\$605 <sup>[19]</sup>	20	\$25,636	12	274,059	18	\$2.2
<a href="#"> Austr</a>	25.4	29	\$1,392	14	\$54,803	2	265,901	20	\$5.2
<a href="#"> Nethe</a>	17.3	30	\$910	17	\$52,601	3	121,062	25	\$7.5
<a href="#"> rlands</a>									
World	7,683	—	\$87,555	—	\$11,395	—	27,044,191	—	\$3.5
<ul style="list-style-type: none"> <li>• Population data is from the <a href="#">World Bank</a><sup>[12]</sup></li> <li>• GDP data is from the <a href="#">World Bank</a><sup>[14]</sup></li> <li>• Electricity data is from <a href="#">BP Global</a><sup>[15]</sup></li> <li>• rank* of Population, GDP, and Electricity generation are rankings within this list</li> <li>• GDP (PPP) / kWh is the amount of GDP (PPP) (USD) produced per <a href="#">kilowatt-hour</a></li> </ul>									

Electricity consumption by sector

The table below lists the 15 countries with the highest final electricity consumption, which

comprised more than 70% of the global consumption in 2022.<sup>[8]</sup>

#### Electricity final consumption by sector (2022)

Country/ Geographical region	Total (TWh)	Industry	Transport	Commercial /Public services	Residential	Agriculture /Forestry	Other
 <a href="#">China</a>	7,214	59.9%	2.4%	7.3%	16.4%	2.2%	11.8%
 <a href="#">United States</a>	4,272	19.9%	0.6%	35.2%	37.4%	2.1%	4.8%
 <a href="#">India</a>	1,403	37.7%	11.2%	7.8%	21.7%	15.9%	5.7%
 <a href="#">Japan</a>	1,132	37%	1.8%	33.7%	27.1%	0.3%	0.1%
 <a href="#">Russia</a>	934	44.8%	11.1%	20.4%	21.1%	2.5%	0.1%
 <a href="#">Canada</a>	595	35.9%	1.5%	28.1%	32.5%	2.0%	0%
 <a href="#">South Korea</a>	553	52.3%	0.6%	31.4%	12.7%	2.5%	0.5%
 <a href="#">Brazil</a>	550	38.3%	0.7%	27.3%	27.7%	6%	0%
 <a href="#">Germany</a>	539	44.8%	2.3%	26.4%	25.4%	1.1%	0%
 <a href="#">France</a>	463	26.9%	2.4%	31.5%	37%	1.9%	0.3%
 <a href="#">Saudi Arabia</a>	317	33.7%	3.9%	28.3%	25%	4.1%	5%
 <a href="#">United Kingdom</a>	312	18.3%	2.2%	38.2%	39.1%	2%	0.2%
 <a href="#">Italy</a>	300	30%	5%	32%	30%	1%	2%
 <a href="#">Mexico</a>	296	29%	4%	33%	30%	3%	1%
 <a href="#">Iran</a>	280	24%	6%	37%	25%	5%	3%
World	24,398	42.2%	1.8%	21.1%	26.8%	3.1%	5%

#### Electricity outlook



This section needs to be **updated**. Please help update this article to reflect recent events or newly available information. (February 2022)

Looking forward, increasing [energy efficiency](#) will result in less electricity needed for a given demand in power, but demand will increase strongly on the account of:<sup>[20]</sup>

- Economic growth in developing countries,<sup>[20]</sup> and
- Electrification of transport and heating. Combustion engines are replaced by electric drive and for heating less gas and oil, but more electricity is used, if possible with [heat pumps](#).<sup>[20]</sup>

The [International Energy Agency](#) expects revisions of [subsidies for fossil fuels](#) which amounted to \$550 billion in 2013, more than four times [renewable energy](#) subsidies. In this scenario,<sup>[21]</sup> almost half of the increase in 2040 of electricity consumption is covered by

more than 80% growth of renewable energy. Many new nuclear plants will be constructed, mainly to replace old ones. The nuclear part of electricity generation will increase from 11 to 12%. The renewable part goes up much more, from 21 to 33%. The IEA warns that in order to restrict global warming to 2 °C, carbon dioxide emissions<sup>[22]</sup> must not exceed 1000 gigaton (Gt) from 2014. This limit is reached in 2040 and emissions will not drop to zero ever.

The [World Energy Council](#)<sup>[23]</sup> sees world electricity consumption increasing to more than 40,000 TWh/a in 2040. The fossil part of generation depends on energy policy. It can stay around 70% in the so-called "Jazz" scenario where countries rather independently "improvise" but it can also decrease to around 40% in the "Symphony" scenario if countries work "orchestrated" for more climate friendly policy. Carbon dioxide emissions, 32 Gt/a in 2012, will increase to 46 Gt/a in Jazz but decrease to 26 Gt/a in Symphony. Accordingly, until 2040 the renewable part of generation will stay at about 20% in Jazz but increase to about 45% in Symphony.


An EU survey conducted on climate and energy consumption in 2022 found that 63% of people in the European Union want energy costs to be dependent on use, with the greatest consumers paying more. This is compared to 83% in China, 63% in the UK and 57% in the US.<sup>[24][25]</sup> 24% of Americans surveyed believing that people and businesses should do more to cut their own usage (compared to 20% in the UK, 19% in the EU, and 17% in China).<sup>[26][27]</sup>

Nearly half of those polled in the European Union (47%) and the United Kingdom (45%) want their government to focus on the development of [renewable energies](#). This is compared to 37% in both the United States and China when asked to list their priorities on energy.<sup>[26][28][29]</sup>

The United States is on track to break electricity consumption records in 2025 and 2026, according to the [U.S. Energy Information Administration](#)'s (EIA) Short-Term Energy Outlook, released in February 2025. With demand from data centers powering artificial intelligence and cryptocurrency operations, alongside rising electricity use in homes and businesses for heating and transportation, the EIA projects total power consumption will hit 4,179 billion kilowatt-hours (kWh) in 2025 and 4,239 billion kWh in 2026—both surpassing the current record of 4,082 billion kWh set in 2024. The forecasted increase can be broken down as follows: residential electricity sales will climb to 1,524 billion kWh in 2025, commercial demand to 1,458 billion kWh, and industrial usage to 1,054 billion kWh. This would mark new highs for the commercial sector, which set its current record of 1,421 billion kWh in 2024, and for residential consumers, whose last peak was 1,509 billion kWh in 2022. Meanwhile, the industrial sector—historically the largest consumer of electricity—remains just below its all-time high of 1,064 billion kWh set in 2000. As AI, cryptocurrency mining, and electrification continue to drive demand, the U.S. power grid faces mounting pressure to keep pace with this record surge in electricity consumption.<sup>[30]</sup>


Topic 2 experimental company    theory practical

2.1 .Overview :

<u>Keyword</u> <u>description</u>		
Update Regarding Your Application		
<b>Inbox</b>  <b>Eaton TalentHub</b> 11:43 AM (1 hour ago)		
to me		

Hi Fiston,

Thank you for applying for the position of Area Sales Manager - Industrial Sales – 40445. We appreciate you considering a career at Eaton. After careful review, we have decided to move forward with other candidates who more closely match the current needs for this team and position.

We know that messages like this are disappointing, but we really hope you continue to pursue other opportunities at Eaton. Be sure to check out [Eaton.com/careers](http://Eaton.com/careers), where you can find all our open jobs and set up a job alert.

Thank you for your interest in Eaton and wish you all the best!

Eaton Talent Acquisition Team

Thank you for choosing Eaton UPS Service Level Agreement

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Thank you for interest in Eaton UPS Service Level Agreement

Dear Tshingombe tshitadi,

Congratulations on taking a step toward peace of mind in the management of your critical power backup solution !

Below is the summary of your requirement, kindly note that this is not an official agreement, if you requested to be contacted by Eaton, our sales team will get in touch to discuss alignment with your maintenance strategy.

We are looking forward to speaking with you,  
UPS Services Team

Choose what should be included in your contract:

Emergency response (8/5 or 24/7)  
Yes

Would you like to minimise your OPEX expenses by including travel and labour costs in the contract?  
Yes

Would you like to include also all spare parts expenses in the contract?  
Yes

Cyber Secured Monitoring - including 24/7 monitoring, remote diagnostic, periodical health reports  
Yes

USP type:	kVA:	UPS Serial no:
BladeUPS	36	30

First Name:	Last Name:
Tshingombe	tshitadi

Email:	Phone no.:
--------	------------

[tshingombefiston@gmail.com](mailto:tshingombefiston@gmail.com)

+27072529846

**Company name:**  
tshingombe

**Country :**  
South Africa

**Service Plan:**  
PREMIUM

[Connect with Eaton:](#)

Eaton is a power management company.  
We provide energy-efficient, hydraulic, electrical and mechanical power more efficiently,  
safely and sustainably.

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Eaton Electric (South Africa) Pty Ltd, Private Bag X019, Wadeville, Gauteng, South Africa, 1422

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Eaton <customerserviceafrica@eaton.com>

10:56 AM (2 hours ago)

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Thank You for contacting **EatonCare**. Our team will address your request shortly. If you have an urgent need, our contact information is:

**Contact Email Address:**

[EatonCareEMEATraining@eaton.com](mailto:EatonCareEMEATraining@eaton.com)

**Contact Phone Number:**

+31 (0)41 85 70 200

**Contact Address:**

1123 Budapest, Hungary; Nagyenyed u. 8-14.

To learn more about your **EatonCare** support team:

[More about EatonCare](#)

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We provide energy-efficient, hydraulic, electrical and mechanical power more efficiently,  
safely and sustainably.

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Eaton Electric (South Africa) Pty Ltd, Private Bag X019, Wadeville, Gauteng, South Africa, 1422

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My profile

Contact details

## Contact Details

### Personal Details

Given Name:

TSHINGOMBE

Email Address:

TSHINGOMBEFISTON@GMAIL.COM

Account type(s):

Supplier

### Company Details

Company Name:

TSHINGOMBE TSHITADI

Country:

ZA

Address:

103 ROCKVIEW YEHOVILL .JHB, 20 PERCY STREET

Zip or Postal Code:

1030

Business Phone:

0725298946

Mobile Phone:

0725298946

[Update Contact Details](#)

Current access

## Current Access

### Application Access:

Eaton University

## Learning & Development Resources

Learning and development resources contains learning activities to help to build your existing knowledge and learn new skills and competencies.

### HR Capabilities

- [Assessing Potential](#)
- [Coaching](#)
- [Change Management](#)
- [Business Acumen](#)
- [Organizational Assessment & Design \(OAD\)](#)
- [Workforce Analytics](#)

### Functional Technical Training

- [Employee & Labor Relations](#)
- [Talent Acquisition Learning Priorities](#)

### Additional HR Learning

- [HR Deployment Calls](#)
- [Revisit Global HR Orientation](#)
- [HR Professional Bundle](#)

## DIGITAL LEARNING CENTER

Eaton's Digital Foundation

Digital transformation is happening at Eaton.

- [Artificial Intelligence Training](#)
- [Digital Transformation Overview](#)
- [Introduction to Functional Productivity](#)
- [Industry 4.0](#)

Digital Mindset

Click on the below resources to learn more.

- [Data Analytics](#)
- [Design Thinking](#)
- [Agile](#)
- [Risk Taking](#)
- [Continuous Improvement](#)
- [Digital Technologies](#)

Learn more about Eaton University for Enterprise

Learn about the biggest digital transformation in learning happening at Eaton.

*Go through the below webinar recordings to know more:*

[Webinar 1](#)     [Webinar 2](#)

Reach out to us via the [Employee Center](#), (select “EU for Enterprise”)

Join the "[Eaton University for Enterprise](#)" yammer channel to get regular updates

Plan your Development

- [LeaderX](#)
- [Talent Hub](#)
- [Bootcamp Calendar](#)
- [Sustainability Report](#)

Top News

- 

*Create classes, Record attendance, Access reports with 80% productivity savings using the Eaton University Classes and Registration system (LMS).*

If you are the EHS Manager, Quality Manager, HR Manager delivering learning at your site, please reach out to [Brooke Atkinson](#) (Americas), [Victoria Chytaylo](#) (EMEA), [Tang Min](#) (APAC) or [Geetanjali Malshe](#) (India and South East Asia) to know more.

Connect with us on the

[Eaton University for Enterprise](#) yammer group to learn more and keep up with launch communications.

- 

Check out the Eaton University EMEA Program Plan here!

What are your learning objectives for this year? Review the Eaton University EMEA [2025 Learning Catalogue](#) for an overview of learning programs by subject, and the [Program Schedule](#) for an overview of scheduled instructor led session in the region to find the best learning solution for you!

- 
- 
-

### [Virtual Classroom Training in My Region](#)

[Explore the list of Virtual Classroom/Virtual Instructor Led training in your region. You can filter further by time zones within your region.](#)

### [Classroom Training in My Country](#)

[Explore the list of Classroom Training in your country. You can also filter by location within your country.](#)

### All Learning Catalog

Explore the list courses in Eaton University for you.

- [EMEA Catalogue](#)
- [AMERICAS Catalogue](#)
- [APAC Catalogue](#)
- [EMEA Schedule](#)
- [China Trainer List](#)
- [APAC Schedule](#)

### Instructions

- This page has powerful features. [Click here](#) to learn the features and how you can use it for your learning needs.
- Once you open the catalog you can filter the results using the “Options” button on the title menu.
- You can also, copy-paste the registration link in the browser to register for the course. An active JOE session is essential for the link to be functional.

### Training Schedule

This is a list of current training activities for which you are registered.

Search:

- [CURRENT/UPCOMING](#)
- [Expressed Interest](#)
- [Pending signatures](#)
- [Completed](#)
- [Canceled](#)
- [Waiting list or pending approval](#)
- [Learner Attachments](#)
  
- [CURRENT/UPCOMINGAll](#)
- [CURRENT/UPCOMINGOngoing Activities](#)
- [CURRENT/UPCOMINGUpcoming Activities](#)
- [CURRENT/UPCOMINGFixed Duration Activities](#)
- [CURRENT/UPCOMINGCompletion Requested Activities](#)

Displaying 7 of 7 Records

Displaying 7 of 7 Records



Registered ETN\_8DPSO\_GBL\_SCM\_CP



In Progress ETN\_8DPSO

10/27/2024



In Progress EDUCYMEAFHA



Registered ETN\_ATLTR



Registered ETN\_ATLTR\_A25      4/28/2025 4/28/2025



In Progress GEIS\_CH\_HLT\_CRHL2



In Progress ETN\_PPTM1



In Progress ETN\_EL\_PPAPO



In Progress EDUTLTPDU

## Training Schedule

Generated By: tshingombe

tshitadi

View: Current activities

Created on: Sunday, February 23, 2025 4:33:19

AM EST

Activity Name	Status	Code	Region	Start Date	End Date
Course Pointer : 8D Problem Solving Overview	Registered	ETN_8DPSO_GBL_SCM_CP			
e-Learning Course : 8D Problem Solving Overview of 8D Problem Solving Overview	In progress	ETN_8DPSO		10/27/2024 7:28 AM EDT	
e-Learning Course : Arc Flash Hazards Assessment and Protection Device Coordination Webinar	In progress	EDUCYMEAFHA		2/22/2025 5:20 AM EST	
Instructor Led Course : Assessing Talent (LeaderX Talent Review Webinars)	Registered	ETN_ATLTR			
Instructor Led Class : Assessing Talent (LeaderX Talent Review Webinars) For EMEA	Registered	ETN_ATLTR_A25		4/28/2025 4:00 AM EDT	4/28/2025 5:00 AM EDT
e-Learning Course : Cabling Requirements in Hazardous Locations - Part II	In progress	GEIS_CH_HLT_CRHL2		2/22/2025 5:39 AM EST	
e-Learning Course :	In	ETN_PPTM1		2/22/2025	

Power press Training Module 1 - PPE & Housekeeping Certification	progr ess			5 5:17 AM EST	
e-Learning Course : Production Part Approval Process - Overview	In progr ess	ETN_EL_PPAP O		2/22/202 5 6:03 AM EST	
e-Learning Course : Switched PDUs (Technical Course)	In progr ess	EDUTLTPDU		2/22/202 5 5:30 AM EST	
<p>TRAINING TRANSCRIPT FOR TSHINGOMBE TSHITADI List of completed activities from 2/23/2024 to 2/23/2025 Username: tshingombefiston@gm ail.com E-mail: TSHINGOMBEFISTON@ GMAIL.COM Primary domain: Global SCM Primary organization: Primary job: User number: tshingombefiston@gm ail.com ACTIVITIES Activity Signature Status Start Date Completion Date Learner Signature</p>					

Date  
 Score Attended  
 Duration  
 Completion  
 Status  
 e-Learning Course:  
 Eaton: Supporting  
 Your CDP Disclosure  
 2/23/2025 2/23/2025  
 Day(s): 0,  
 Hour(s): 0,  
 Minute(s): 0,  
 Second(s): 53  
 Attended  
 e-Learning Course:  
 Eaton's Low-Voltage  
 Switchgear  
 2/22/2025 2/22/2025  
 Day(s): 0,  
 Hour(s): 0,  
 Minute(s): 2,  
 Second(s):  
 26.3  
 Attended  
 e-Learning Course:  
 Eaton Electrical - SEM  
 + Addendum  
 2/22/2025 2/22/2025  
 16.67  
 Failed  
 Day(s): 0,  
 Hour(s): 0,  
 Minute(s): 2,  
 Second(s): 23  
 Attended  
 e-Learning Course:  
 Sales Training Exam:  
 Eaton G4 Rack PDUs  
 2/22/2025 2/22/2025  
 55.55

Failed

Day(s): 0,  
Hour(s): 0,  
Minute(s): 0,  
Second(s):  
59.2

Attended

e-Learning Course:  
Sales Training Exam:  
How to Sell More  
Cables and  
Connectivity  
2/22/2025 2/22/2025

80 Day(s): 0,  
Hour(s): 0,  
Minute(s): 0,  
Second(s):  
42.6

Attended

e-Learning Course:  
Surge Solutions  
2/22/2025 2/22/2025  
25

Failed

Day(s): 0,  
Hour(s): 0,  
Minute(s): 2,  
Second(s):  
10.3

Attended

e-Learning Course:  
Power press Training  
Module 1 - PPE &  
Housekeeping  
10/27/2024 2/22/2025

Day(s): 0,  
Hour(s): 0,  
Minute(s): 1,  
Second(s): 14

Attended

e-Learning Course:  
Functional Skills  
Workshop: Human  
Resources [eLearning]  
2/21/2025 2/21/2025  
Day(s): 0,  
Hour(s): 0,  
Minute(s): 1,  
Second(s): 19  
Attended  
e-Learning Course:  
Power press Training  
Module 1 - PPE &  
Housekeeping  
10/27/2024  
10/27/2024 Day(s): 0,  
Hour(s): 0,  
Minute(s): 0,  
Second(s): 17  
Attended

**Thank you for your  
application, Fiston!**

**Review your profile  
information and skills  
to increase your  
chances of getting  
hired.**

---

---

Profile Review

- 

Skill  
Assessment

Fiston Tshingombe

[tshingombefiston@gmail.com](mailto:tshingombefiston@gmail.com)

Email

[https://www.linkedin.com/in/tshingombe\\_tshitadi-9b6204123](https://www.linkedin.com/in/tshingombe_tshitadi-9b6204123)

Links

Johannesburg, South Africa

Location

[+27723456770](tel:+27723456770)

Phone

## Work Experience<sup>1</sup>

### *Engineering*

Jacobs Engineering

Feb 2020 - Present

engineering electrical  
design analyse  
investigation  
component

## Education<sup>1</sup>

*UNIVERSITÉ De  
Kinshasa UNIKIN*

Certificate, Engineering

Oct 2020 - Jan 2023

Study Program st  
peace college 10/2020  
- Present, jhb r Courses  
engineering electrical

#### **Awards<sup>1</sup>**

##### *Panel wiring electrical*

St peace college

Mar 2024

Panel wiring award  
certificate. Outlet  
socket. db .

#### **Patents<sup>1</sup>**

##### *Ccma laboure*

Mar 2024

Ccma labour

#### **Publications<sup>1</sup>**

##### *Education technology*

Tshingombe

Mar 2024

Education technologie  
trade electrical  
elementaire  
fundamental

## My Applications

Applications

Saved Jobs

Showing 53 Jobs

Area Sales Manager - Industrial Sales

40445

Feb 23, 2025

Application Processing

Nashville, Tennessee, USA, 37211

Production Technician

38169

Jan 16, 2025

No Longer Under Consideration

La Vergne, Tennessee, USA, 37086

Eaton Development Program: Power Systems Automation and Controls Engineer

31008

Jan 10, 2025

Application in Review

Moon Township, Pennsylvania, USA, 15108

Statutory and Tax Analyst

36199

Dec 12, 2024

Application in Review

Johannesburg, Gauteng, ZAF, 1619

Battery Technical Specialist

36800

Dec 12, 2024

Application in Review

Montbonnot Saint Martin, FRA, 38330

EHS Manager - Southeast

36045

Nov 30, 2024

No Longer Under Consideration

Arden, North Carolina, USA, 28704

Power Systems Engineering Manager

36590

Nov 30, 2024

No Longer Under Consideration

Deerfield Beach, Florida, USA, 33442

ReSurge Program: Business Healthcare Development Analyst  
35449

Nov 23, 2024

No Longer Under Consideration

Nashville, Tennessee, USA, 37211

Project Manager - Power Systems Controls  
35679

Nov 14, 2024

No Longer Under Consideration

Littleton, Colorado, USA, 80120

Regional Sales Leader Aftermarket Africa  
35244

Nov 13, 2024

Application in Review

Johannesburg, Gauteng, ZAF, 1619

Principal Design Engineer, Gas Insulated Switchgear (GIS)  
24170

Oct 23, 2024

No Longer Under Consideration

Greenwood, South Carolina, USA, 29649

EMEA Research & Development Senior Subject Matter Expert - Medium Voltage standards  
& applications

32409

Oct 20, 2024

No Longer Under Consideration

Hengelo, NLD, 7559

Internship Program: Field Service Engineer  
30657

Oct 8, 2024

Processed

Moon Township, Pennsylvania, USA, 15108

Senior Project Engineer  
33025

Oct 8, 2024

No Longer Under Consideration

Nashville, Tennessee, USA, 37211  
Service Centre Helpdesk Coordinator  
33335

Sep 28, 2024

No Longer Under Consideration

Johannesburg, Gauteng, ZAF, 1619  
Lead Design Engineer  
33175

Sep 22, 2024

No Longer Under Consideration

Louisville, Kentucky, USA, 40299  
Field Services Engineer - UPS  
32511

Sep 10, 2024

No Longer Under Consideration

Johannesburg, Gauteng, ZAF, 1619  
Senior Field Service Representative  
31161

Sep 5, 2024

No Longer Under Consideration

Nashville, Tennessee, USA, 37211  
Utility Service Sales Specialist  
32009

Sep 5, 2024

No Longer Under Consideration

Charlotte, North Carolina, USA, 28269  
Senior Field Service Representative  
31188

Aug 29, 2024

No Longer Under Consideration

Nashville, Tennessee, USA, 37211

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0 results

FT

My Applications

Applications

Saved Jobs

Showing 53 Jobs

Field Service Engineer

30764

Aug 29, 2024

Job Filled - Other Candidate Selected

RIYADH, Riyadh, SAU, 12482

Technical Services Engineering MFG Technician

30256

Aug 25, 2024

Job Filled - Other Candidate Selected

Arecibo, Puerto Rico, USA, 00612

Commercial Finance Manager

31056

Aug 18, 2024

No Longer Under Consideration

Johannesburg, Gauteng, ZAF, 1619

Key Account Manager - Data Centre Accounts

31211

Aug 18, 2024

No Longer Under Consideration

Johannesburg, Gauteng, ZAF, 1619

Engineering Manager - Power Electronics CoE

24619

Jun 25, 2024

No Longer Under Consideration

Titchfield, GBR, PO14 4QA

Field Service Engineer - UPS

26849

May 29, 2024

No Longer Under Consideration

Johannesburg, Gauteng, ZAF, 1619

Power Systems Engineering Specialist (Expert)

25412

May 19, 2024

No Longer Under Consideration

Milton, Ontario, CAN, L9T 5C3

Manager Engineering Product Design Connected Solutions

25058

May 19, 2024

No Longer Under Consideration

Santo Domingo, DOM

Field Service Engineer - UPS

26105

May 19, 2024

No Longer Under Consideration

Cape Town, ZAF, 7550

Service Centre Helpdesk Coordinator

20686

Mar 6, 2024

No Longer Under Consideration

Johannesburg, Gauteng, ZAF, 1619

Field Services Engineer - UPS

20228

Mar 2, 2024

No Longer Under Consideration

Durban, ZAF, 4017

Field Services Engineer - UPS

19852

Feb 10, 2024

No Longer Under Consideration

Cape Town, ZAF, 7550

Quality Auditor, Training program, 3rd Shift

19275

Feb 9, 2024

Processed

Rumford, Rhode Island, USA, 02916

Lead Power Systems Engineer

19197

Jan 31, 2024

No Longer Under Consideration

El Paso, Texas, USA, 79912

Product Manager - Electrical Working Training & Remote Services

18926

Jan 31, 2024

No Longer Under Consideration

Moon Township, Pennsylvania, USA, 15108

Finance Early Talent Leadership Development Program (m/w/d)

18647

Jan 31, 2024

No Longer Under Consideration

Bonn, DEU, 53115

Finance Early Talent Leadership Development Program

18817

Jan 31, 2024

No Longer Under Consideration

Budapest, HUN, 1123

Site Manager South Africa - Customer Projects

12131

Dec 16, 2023

No Longer Under Consideration

Johannesburg, Gauteng, ZAF, 1619

Engineering Technician - Mechanical

13241

Dec 11, 2023

No Longer Under Consideration

Wilsonville, Oregon, USA, 97070-8247

Lead Engineer Power Conversion

14106

Dec 10, 2023

No Longer Under Consideration

Bonn, DEU, 53115

<

123

>

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0 results

FT

My Applications

Applications

Saved Jobs

Showing 53 Jobs

Senior Power Electronics HW Engineer

5488

Dec 10, 2023

No Longer Under Consideration

Bonn, DEU, 53115

Mechanical Design Engineer - Electrical Vehicle (m/w/d)

14843

Dec 10, 2023

No Longer Under Consideration

Bonn, DEU, 53115

Manager Engineering - Engineering Center (Eplan) ESS EMEA

12431

Dec 10, 2023

No Longer Under Consideration

Hengelo, NLD, 7559

Senior Electrical Project Engineer

15841

Dec 5, 2023

Job Filled - Other Candidate Selected

Dublin, IRL, 4

Applications Engineer

13964

Dec 5, 2023

No Longer Under Consideration

Mascot, New South Wales, AUS, 2020

Project Management Engineer

10396

Dec 5, 2023

No Longer Under Consideration

Selangor, MYS, 46050

Service Engineer - Power Quality

4449

Dec 3, 2023

No Longer Under Consideration

Warszawa, Mazowieckie, POL, 02555

Internship: Engineering Summer - Lincoln, IL

11161

Dec 3, 2023

No Longer Under Consideration

Lincoln, Illinois, USA, 62656

Senior Electrical Engineer

13779

Dec 3, 2023

No Longer Under Consideration

Raleigh, North Carolina, USA, 27616

Electrical Tender Engineer

12618

Dec 3, 2023

No Longer Under Consideration

New Cairo City, EGY, 11835

Project Management Leader South Africa - Customer Projects

12134

Dec 1, 2023

No Longer Under Consideration

Johannesburg, Gauteng, ZAF, 1619

Project Manager South Africa - Customer Projects

12130

Dec 1, 2023

No Longer Under Consideration

Johannesburg, Gauteng, ZAF, 1619

Field Service Engineer - UPS

15094

Dec 1, 2023

No Longer Under Consideration

Durban, ZAF, 4017

<

123

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#WhatsNextForYou

Completion Notification for Eaton's Low-Voltage Switchgear

Inbox



eeetraining@eaton.com Sat, Feb 22, 1:00 PM (21 hours ago)

to me

Dear tshingombe tshitadi,

Congratulations on the successful completion of Eaton's Low-Voltage Switchgear.

**Activity Name:** Eaton's Low-Voltage Switchgear

**Completion Date:** 2/22/2025 5:56:15 AM EST

For a complete copy of your training transcript, please follow the steps below:

**External Learners:**

1. Login to Eaton University through My.Eaton
2. Go to the Self menu in the top left corner
3. Select Reporting > Training Transcript
4. To change the date range, click on the filter in the top left corner

**Eaton Employees:**

1. Login to Eaton University Classes & Registration System (JOE – My Applications)
2. Go to the Self menu in the top left corner
3. Select Reporting > Training Transcript
4. To change the date range, click on the filter in the top left corner

We appreciate your input and look forward to fulfilling your future learning needs.

If you have any questions or concerns, please contact us at

[ESASalesEnablement@eaton.com](mailto:ESASalesEnablement@eaton.com)

Completion Status for Eaton Electrical - SEM + Addendum

**Inbox**



eatonuniversityalerts@eaton.com Sat, Feb 22, 12:55 PM (21 hours ago)

to me

Powered by **EatonUniversity**

Completion Status Notification

Dear tshingombe tshitadi,

**Sorry, you have not successfully completed the following activity. Please follow the steps given below to re-attempt the course.**

- 1. Take the e-Learning course again.**
- 2. Pass the assessment to complete the course.**

**Activity Code:** ETN\_EN\_EESA

**Activity Name:** Eaton Electrical - SEM + Addendum

**Completion Date:** 2/22/2025 5:51:34 AM EST

**Pass Status:** No

**To view your Pass or Fail Status for this attempt, please visit you "My Training Completions". Please follow the instructions provided below.**

For accessing Training completions and diploma certificates:

1. Login to Eaton University Classes & Registration System (JOE – My Applications)
2. Go to “My Training Completions” from Learning dashboard.
3. You can filter on date range as required
4. Click on the certificate icon against respective training to view the certificate
5. Print or Export to pdf using the buttons.

We look forward to serving your future development needs.

**Important:** To help us improve this course, please complete this short [survey](#) (optional).

Thanks and Regards,

**EatonUniversity**

Please do not reply to this system generated email. For any questions or assistance, open a service request with Eaton University. To open a service request, open JOE> click on HR Services Catalog (Employee Center) > Search "Eaton University" and login your request.

(ensure to have active JOE and OKTA).

Completion notification and survey for Sales Training Exam: How to Sell More Cables and Connectivity

Inbox



**eatonuniversityalerts@eaton.com** Sat, Feb 22, 12:40 PM (21 hours ago)

to me

Dear tshingombe tshitadi,  
Congratulations on the successful completion of:

**Activity Name: Sales Training Exam: How to Sell More Cables and Connectivity**  
**Completion Date: 2/22/2025 5:38:21 AM EST**

**Important:** To help us improve this course, please complete this short [survey](#) (optional).  
We look forward to serving your future development needs.

Thank you,  
Eaton University

Completion notification and survey for Sales Training Exam: How to Sell More Cables and Connectivity

Inbox



**eatonuniversityalerts@eaton.com** Sat, Feb 22, 12:40 PM (21 hours ago)

to me

Dear tshingombe tshitadi,

Congratulations on the successful completion of:

**Activity Name:** Sales Training Exam: How to Sell More Cables and Connectivity

**Completion Date:** 2/22/2025 5:38:21 AM EST

**Important:** To help us improve this course, please complete this short [survey](#) (optional).  
We look forward to serving your future development needs.

Thank you,  
Eaton University

Registration confirmation for Assessing Talent (LeaderX Talent Review Webinars) For EMEA

Inbox



eatonuniversityalerts@eaton.com Sat, Feb 22, 12:35 PM (21 hours ago)

to me

Assessing Talent (LeaderX Talent Review  
Webinars) For EMEA

[View on Google Calendar](#)

Apr28Mon

When Mon Apr 28, 2025 10am – 11am  
(SAST)

Where (VILT)/Virtual Instructor Led Training

Who eatonuniversityalerts@eaton.com\*

Agenda

Mon Apr 28, 2025

*No earlier events*

10am Assessing Talent (LeaderX Talent Review Webinars) For EMEA

*No later events*

Powered by [EatonUniversity](#)

Registration Confirmation Notification

Dear tshingombe tshitadi,

You have been successfully registered for the below activity.

Course code- [ETN\\_ATLTR\\_A25](#)

Course Name - [Assessing Talent \(LeaderX Talent Review Webinars\) For EMEA](#)

Start Date: 4/28/2025 10:00:00 AM CEST

End Date: 4/28/2025 11:00:00 AM CEST

Facility and Location: **Location: Virtual Instructor Led Training**

**Facility: (VILT)**

Completion notification and survey for Surge Solutions

Inbox



**eatonuniversityalerts@eaton.com** Sat, Feb 22, 12:30 PM (22 hours ago)

to me

Dear tshingombe tshitadi,  
Congratulations on the successful completion of:

**Activity Name: Surge Solutions**

**Completion Date: 2/22/2025 5:28:37 AM EST**

**Important:** To help us improve this course, please complete this short [survey](#) (optional).  
We look forward to serving your future development needs.

Thank you,  
Eaton University

Registration confirmation for Arc Flash Hazards Assessment and Protection Device  
Coordination Webinar

Inbox



**eatonuniversityalerts@eaton.com** Sat, Feb 22, 12:25 PM (22 hours ago)

to me

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## Registration Confirmation Notification

Dear tshingombe tshitadi,

**You have been successfully registered for the below activity.**

Course code- [EDUCYMEAFHA](#)

Course Name - [Arc Flash Hazards Assessment and Protection Device Coordination Webinar](#)

### User Notes and login details:

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**To open a service request**, open JOE> click on Employee Center > Search "Eaton University" and login your request.  
(ensure to have active JOE and OKTA).

When you have completed this activity, you will receive a completion email that includes a link to **complete a survey**. We greatly appreciate any feedback you can provide to help us improve the course.

Thanks and Regards,

[EatonUniversity](#)

Registration confirmation for Power press Training Module 1 - PPE & Housekeeping

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[eatonuniversityalerts@eaton.com](mailto:eatonuniversityalerts@eaton.com) Sat, Feb 22, 12:20 PM (22 hours ago)

to me

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Registration Confirmation Notification

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Course code- [ETN\\_PPTM1](#)

Course Name - [Power press Training Module 1 - PPE & Housekeeping](#)

**Instructions to access**

1. Open or login to JOE Homepage
2. Select "Eaton University Classes & Registration" from the "My Applications" section.
3. Once the Eaton University Classes & Registration homepage opens, scroll down to the "To Do" section to locate the course.
4. Please click on start button to launch the course.

**Important**

To ensure successful completion of an eLearning course:

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- Use IE11 in compatibility mode and disable any pop-up blockers.
- Carefully follow course exit instructions.

**User Notes:**

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Thanks and Regards,

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Registration confirmation for Power press Training Module 1 - PPE & Housekeeping

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Dear tshingombe tshitadi,

**You have been successfully registered for the below activity.**

Course code- [ETN\\_PPTM1](#)

Course Name - [Power press Training Module 1 - PPE & Housekeeping](#)

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**User Notes:**

When you have completed this activity, you will receive a completion email that includes a link to complete a survey. We greatly appreciate any feedback you can provide to help us improve the course.

Completion notification and survey for Functional Skills Workshop: Human Resources [eLearning]

**Inbox**



[eatonuniversityalerts@eaton.com](mailto:eatonuniversityalerts@eaton.com) Fri, Feb 21, 12:35 PM (2 days ago)

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Activity Completion Notification

Dear tshingombe tshitadi,

**Congratulations on the successful completion of:**

**Activity Code:** ETNFRFSWHR\_EL

**Activity Name:** Functional Skills Workshop: Human Resources [eLearning]

**Completion Date:** 2/21/2025 5:30:26 AM EST

**Important:** To help us improve this course, please complete this short [survey](#) (optional).

Wishing to share the accomplishments with your friends, colleagues, and family? If yes,

1. [Click here](#) to download the certificate of completion in PDF format. Note: An active [JOE](#) (refresh JOE if it has been open for a while) session must be opened to access the download link.
2. Login to your social media platforms (Viva Engage (Yammer), LinkedIn, Twitter, Instagram, Facebook)
3. Create a post, write your caption, attach the downloaded PDF and add the #EatonUniversity and #Eaton hashtags. This post is voluntary.

Here is the suggested text for using as the caption for your post:

*Employees at @Eaton are encouraged to continuously learn, share and grow in their careers. The #Eaton curated learning and development platform, #EatonUniversity, makes that possible. I recently completed a course in Functional Skills Workshop: Human Resources [eLearning]. I'm grateful for these on-the-job opportunities that advance our knowledge, improve performance and help us grow. #whatmatters #lifeateaton #learninganddevelopment.*

We look forward to serving your future development needs.

Thanks and Regards,

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An explosion 4x hotter than the sun

The mere drop of a tool or accidental contact with electrical systems can set off an arc flash and instantly generate an energy explosion releasing temperatures in excess of 36,000°F.

That's four times hotter than the sun.

Why arc flashes occur

An arc flash is the explosive energy released when an electrical fault, for instance a short circuit, causes an arc. The dangers associated with an arc flash event include heat, flying debris, sound, UV radiation and more.

2

3

5

7

6

4

1

Power intensive environments are especially vulnerable

In heavy power, continuous operation industries, arc flash poses a very real threat. Environments operating with 125 kVA or larger transformers call for special safety measures.

Protecting personnel and equipment is everyone's responsibility.

8

Employees require education

Electrical workers must be trained and should understand the risks of arc flash safety. This includes reading and understanding arc flash labels and wearing the proper personal protective equipment (PPE) to perform energized work. Codes and standards are always changing and it is imperative that your organization be in compliance.

Arc flash labels provide advance warning

Arc flash labels indicate two key pieces of information: The expected incident energy (measured in calories per cm<sup>2</sup>)—at a working distance of 18 inches or 24 inches—which drives the proper PPE required for protection. And the distance a worker without PPE must work to avoid a non-curable burn (typically measured in feet).

Avoiding electrical disasters

Time and distance are the most controllable variables reducing the risk of arc flash issues. Reducing the time that an event persists by tripping a breaker or blowing a fuse significantly reduces the arc flash incident energy.

Increasing distance to the arc flash by remote operation, or with closed doors or protective barriers, protects workers in case an event occurs.

Better equipment can help

Installing the right equipment can help mitigate arc flash hazards. Specially designed low voltage motor control centers (MCCs) and switchgear can reduce the probability of electrical shock and arc flash energy during maintenance.

As powerful as an 8-stick dynamite blast

A 10,000A arc on a 480-volt circuit can have the explosive force of eight (8) sticks of dynamite.

Another example of the energy in an arc flash: copper expands at 67,000 times its volume during an arc flash event—a small, pea-sized piece of copper would expand to fill the volume of a railroad car!

9

10 Good safety optimizes operational efficiency

A sound safety policy incorporating arc flash safety solutions will protect your people and equipment, minimizing risk and increasing uptime.

Human error is often to blame

The most common cause of electrical accidents is human error. And the majority of those mistakes occur during routine maintenance of power system equipment or troubleshooting controls.

Follow the Charge »

to consider when designing your data center

10 THINGS ABOUT

ARC FLASH SAFETY Each year, Eaton is performing discharge tests for over 300 000 batteries in Finland, where the EMEA UPS factory is located, to guarantee the safety and the functionality of the complete battery system.

Eaton has a performing battery approval process, that leads to utilizing only the premium batteries on the market. In addition, regular audits are performed in all the facilities of the approved battery suppliers of Eaton

Battery replacement service

Batteries are the core element of any critical power protection system, hence they are assuring the backup time delivery. Most frequent cause of unplanned outages is premature end of life of few battery blocks.

Handling batteries without proper training can lead to disastrous results

of full UPS system investment

30-80%

+ -

Continuous quality monitoring

Eaton is utilizing millions of batteries per year for UPS applications globally. Battery quality indeed plays the most critical role in battery

selection criteria.

>300 000 BATTERIES>1 000 000

Batteries

utilized

globally

TESTED FOR EATON 3PH UPS

IN EMEA PER YEAR

As identical as possible battery performance between each battery blocks in the same string is

crucial for the battery lifetime and battery string performance. In the graphs there are real test

results from the same discharge test for 20 blocks of lower quality and 20 blocks of high quality

batteries. With lower quality batteries there is much higher dispersion in the graphs than with

high quality batteries.

Eaton EMEA 3ph UPS service

Good quality battery example Low quality battery example

End of discharge

Time

Voltage

Time

Voltage

End of discharge

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## Safety ensured

With over 50 years of experience in qualifying batteries for UPS applications, Eaton is replacing more than 200 000 blocks every year in EMEA. Eaton field service engineers and authorized partners are trained to perform the battery replacement according to the required safety procedures.

In addition, Eaton's trained personnel is able to set and operate UPS and battery according to the site specific requirements, like environmental temperature and humidity, and Eaton UPS features like ABM, ESS and VMMS. This is crucial for safety and optimal UPS system performance.

As an active steward of the environment, Eaton guarantees an efficient disposal of the end-of-life batteries.

To benefit from battery replacement and other features, Eaton offers Service Level Agreements for maintaining the condition of your UPS to ensure its continuous performance while allowing you to accurately plan your budget.

For more information about UPS services please visit <https://www.eaton.com/gb/en-gb/services.html>

>200 000 BLOCKS  
REPLACED PER YEAR

Years of  
expertise with

UPS batteries

50+ >4000 A

can be  
delivered

from a

battery

cabinet

ABM

A correct set-up

of the charging

method promotes

battery life

- Relevance
- A-Z
- Z-A

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Configure. Review. Complete. Order.

Plan your service according to your maintenance needs and budget

- Basic: professional routine maintenance for your UPS
- Standard (+): essential services to minimize failure rate and its impact ("+" supported by Cyber Secured Monitoring)
- Advanced (+): your choice to optimize maintenance investment ("+" supported by

### Cyber Secured Monitoring)

- Premium: integral solution to maximize your power security supported by Cyber Secured Monitoring

Choose what should be included in your contract:

Emergency response (8/5 or 24/7)

Yes No

Travel and labour costs

Yes No

All spare parts expenses

Yes No

Cyber Secured Monitoring - including 24/7 monitoring, remote diagnostic, periodical health reports

Yes No

UPS type \*

kVA \*

UPS Serial no.

Flexible energy systems will power the future

The transition to a more sustainable, low-carbon future is accelerating. This energy transition is driven by the progressive replacement of carbon-based fuels with renewables, clean air regulation and the direct and indirect electrification of more applications.

Today, energy flows through the grid in more directions and through more devices than ever before, and although that decentralisation creates more complexities and challenges, it also creates new potential. [Everything as a Grid](#) is our approach to reinventing the way power is distributed, stored and consumed.

Our Everything as a Grid approach is shaping a future where homeowners and businesses can reduce the cost and environmental impact of energy. Flexible, intelligent power creates new opportunities for everyone.

## Energy transition: Everything as a Grid

Our Everything as a Grid approach reinvents how power is distributed, stored and consumed worldwide. Because the world's energy needs are shifting, but what matters isn't. [Eaton.com/EnergyTransition](https://www.eaton.com/energytransition)

[Watch the full story](#)

The transition to renewable power

Global renewable adoption is on the rise; electricity demand is expected to reach 38,700 terawatt-hours by 2050 – with renewables providing 50% of that energy.<sup>1</sup>

The highly distributed nature of renewable energy is upending the traditional power delivery model. Electricity no longer flows in one direction from the utility that generates it to those who consume it. The new energy ecosystem comprises an intricate network of “prosumers” – consumers and businesses who produce their own energy locally, use what's needed and in many cases, are looking to export excess power back to the grid. Furthermore, the electrification of transport, building systems and industrial processes will drive considerable increases in demand for electrical power over the coming decades. Data centers, offices, factories and similar sites can participate in the transition via battery and thermal energy storage systems and grid-interactive uninterruptible power systems.

This will give rise to vast bi-directional electricity flows requiring a network with the flexibility to cope with higher volatility and demand.

57

%

Increase in global electricity demand by 2050

13X

Growth in energy storage installed base by 2030

4X

Growth of electricity required for data and computing by 2030

Planning for the shift to more electrical power

The electrification of more areas of the economy, including transport, building systems and industry will drive a substantial increase in power demand by 2050. It is technically feasible to meet this extra demand with electricity generated from low or zero carbon sources. However, this will require concerted government support through policy and regulation as well as research and development to reduce the cost of new green energy sources like clean

hydrogen.

#### Decarbonisation: cleaner power

Businesses and consumers are participating in cleaner power initiatives. Active corporate sourcing of renewable electricity reached 465 terawatt-hours (TWh), with production for self-consumption reaching 165TWh.<sup>2</sup> On the consumer side, electric vehicle (EV) charging technology prices continue to fall, while charging point accessibility continues to rise.

By facilitating the trading of self-generated clean electricity to reduce energy costs, we're enabling energy users, both consumers and businesses, to participate in demand response programmes where the utility can turn demand and/or on-site generation up or down in response to signals for real-time grid balancing needs.

#### Democratisation: less reliance on the grid

More homes, businesses and communities are becoming self-sufficient power producers that rely less on the utility grid. They generate, store and consume their own energy via renewable [solar arrays](#), wind turbines, microgrids and battery storage. And they create a bi-directional flow that is changing the way power is managed and reducing the impact of sudden outages caused by rolling blackouts, cyberattacks and extreme weather events. These prosumers may also sell excess energy back to the grid and take advantage of demand response programmes to help reduce utility bills.

#### Digitalisation: connectivity behind powerful decisions

[Digital innovation](#) can be used to make smarter business or personal energy management decisions. It's the transformation of the data from appliances, equipment or processes into actionable insights that help consumers and businesses drive new efficiencies, maximise uptime and manage their energy footprint.

Through technologies that support bi-directional power generation, storage and energy management, we're playing a critical role in helping meet demand growth and balance grid volatility. We are reimagining and rebuilding the electrical power value chain.

Need help with the shift to more electrical power?

[Contact us](#)

#### Embracing the new power paradigm

Homes, offices, stadiums, factories and data centres can now generate and store more of their own power to optimise energy costs, lower their carbon footprint and in some cases,

reduce reliance on the grid. This is [Everything as a Grid](#).

Traditional electrical power infrastructures must be upgraded, with software and services optimising every process, to realise new energy benefits. We enable a systems approach to infrastructure integration and the technologies that help transform power generation and distribution for homes, buildings and utilities.

### [Buildings as a grid](#)

Unlock the energy transition for your building

See how the energy transition can help you seize the opportunity to [improve the performance and expand functional use of your building infrastructure](#).

Eaton introduces its Buildings as a Grid approach to energy transition  
Eaton introduces its Buildings as a Grid approach to help customers accelerate decarbonization, boost resilience, reduce energy costs and create new revenue streams.

Responding to the high demand for low carbon

Renewable and battery market shares continue to rise and play a larger role in the global power supply, even in the wake of the COVID-19 pandemic. The steady increase of competitiveness in [renewables](#), along with their modularity, rapid scalability and job creation potential, make them highly attractive as countries and communities evaluate economic stimulus options.<sup>3</sup>

The challenge lies in balancing variable renewable power and storage options against the always-there, always-on power that users demand. By helping utilities, building managers and homeowners adopt renewable power and storage strategies, we're helping to make clean energy available when and where it's needed.

### Energy storage

Capture renewable energy whenever it's available and use it on demand. You'll see immediate gains in reliability, realise greater independence from the utility grid and avoid dips in grid power supply due to brownouts, cyberattacks and weather-related events. This transformational technology revolutionises power for all, with energy storage available for the home, commercial and industrial buildings and even large-scale implementations for utilities.

## EnergyAware UPS

Our [EnergyAware](#) technology helps applications like data centres to support energy providers by balancing sustainable power generation and consumption. The technology optimises power usage during peak demand hours and helps facilities earn additional revenues from currently deployed assets while maintaining complete control of deployed uninterruptible power systems and batteries.

## Electric vehicles

Changing energy demands will affect infrastructure investments – and understanding that impact will be critical in enabling a resilient systems approach that seamlessly and flexibly integrates different assets and EV infrastructure. Power systems, EV manufacturers and [charging infrastructure](#) providers can then drive a deeper understanding of energy usage to maximise energy efficiency and lower operational costs to consumers.

## Microgrids

Built to help isolate power from the main grid, [microgrids](#) balance multiple sources of on-site generation and demand to make energy available when it is needed.

## Grid modernisation

Discover how utilities can adopt [grid modernisation](#) technologies to build resilient, efficient and secure power networks.

Find out more about Eaton's global sustainability commitments, including carbon neutrality by 2030

[Find out more](#)

## Adapting to fast-changing regulations

Regulators are starting to make important changes to incentivise services like demand response to reduce costs, encourage and integrate the uptake of clean energy and increase customer participation. However, we have far to go if we are to replicate best practices and further encourage innovation. This includes financial mechanisms that reward utilities and distribution companies for contracting with distributed energy providers in place of capital investments – a departure from traditional regulation in which the addition of new capital assets is the main source of profit. Through market data analysis and expert insights, we help companies and countries prepare for and embrace the regulatory changes needed to assure a reliable power mix.

## Ensuring cybersecurity throughout the transition

Only 48% of utility executives feel they are prepared to handle the challenges of a cyberattack interruption.<sup>4</sup> As utilities address the challenges of improving power reliability and efficiency, they must also contend with the near-constant barrage of security threats.

We proactively address cyber threats via a system-wide defensive approach and an unwavering focus on the dangers malware, spyware and ransomware present across the globe. Our team members meet and exceed competencies recognised by international standards organisations like UL, IEC, ISA and others through rigorous, in-depth technical training programmes. Our ["secure-by-design" philosophy, processes and secure development lifecycle](#) are integrated into product development and guide our labs, procurement and design teams as the foundation of innovation. And our understanding of and influence in changing global standards help guide safer, more efficient energy infrastructures.

## Powering the energy transition

The technologies that convert wind and sunlight to renewable energy have matured, allowing for more flexible power possibilities. The growth of renewables, localised electricity production and bi-directional energy helps more homes, businesses and communities produce their own clean, dependable energy for less reliance on the utility grid. Count on Eaton for the technologies and digital intelligence needed for you to join this energy transition. Through our Everything as a Grid approach, infrastructures can be re-vamped to manage and optimise renewable integration, so you can realise more efficient, sustainable power that costs less.

### MTL4500/MTL5500 range

Analogue Input Modules with passive input for  
4-wire separately powered transmitters

MTL4541A, MTL4541AS, MTL5541A, MTL5541AS,

MTL4544A, MTL4544AS, MTL5544A, MTL5544AS

April 2024

SM4541A/AS, 5541A/AS,  
4544A/AS, 5544A/AS rev 2

Safety manual

MTL intrinsic safety solutions

FUNCTIONAL SAFETY MANAGEMENT

These products are for use as elements within a Safety System conforming to the requirements of IEC

61508:2010 and enable a Safety Integrity Level of up to SIL 2 to be achieved for the instrument loop in a simplex architecture.

Eaton Electric Ltd, Luton is a certified Functional Safety Management company meeting the requirements

of IEC61508:2010 Part 1, Clause 6.

\*

\* Subject to special conditions for detection of out-of-range signal currents. Refer to content of this manual for details.

SIL

IEC 61508:2010

2

2SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2

This manual supports the application of the products in functional-safety related loops. It must be used

in conjunction with other supporting documents to achieve correct installation, commissioning and operation. Specifically, the data sheet, instruction manual and applicable certificates for the particular product should be consulted, all of which are available on the MTL web site.

In the interest of further technical developments, Eaton reserve the right to make design changes.

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Analogue Input Modules with passive input for 4-wire transmitters

Hardware Fault Tolerance (HFT) †

Module type 0, 1

MTL4541A,

MTL4541AS,

MTL5541A,

MTL5541AS,

MTL4544A,

MTL4544AS,

MTL5544A,

MTL5544AS

† These modules have an inherent fault tolerance of 0.

SIL

IEC 61508:2010

2

3SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2

1 INTRODUCTION

1.1 Application and function

The Analogue Input module types MTLx541A/MTLx541AS (single channel) and MTLx544A/MTLx544AS

(dual channel) are intrinsic safety isolators that interface with process measurement transmitters located in

a hazardous area of a process plant. They are also designed and assessed according to IEC 61508 for use in

safety instrumented systems up to SIL 2.

The MTLx541A provides an input for a separately-powered 4/20mA transmitter located in a hazardous

area, and repeats the transmitter current into a load in the safe area. The MTLx544A supports two identical

channels for use with two separate transmitters. The MTLx541AS and MTLx544AS versions act as a current

sink for the safe area connection rather than driving the current into the load.

All the modules allow bi-directional transmission of HART communication signals superimposed on the 4/20mA loop current, so that the transmitter can be interrogated either from the operator station or by a hand-held communicator (HHC).

There are no configuration switches or operator controls to be set on the modules. These modules are members of the MTL4500 and MTL5500 range of products.

## 1.2 Variant Description

Functionally the MTL4500 and MTL5500 range of modules are the same but differ in the following way:

- the MTL4500 modules are designed for backplane mounted applications
- the MTL5500 modules are designed for DIN-rail mounting.

In both models the hazardous area field-wiring connections (terminals 1,2, and optionally 4,5) are made through

the removable blue connectors, but the safe area and power connections for the MTL454xA/MTL454xAS

modules are made through the connector on the base, while the MTL554xA/MTL554xAS modules use the

removable grey connectors on the top and side of the module.

Note that the safe-area connection terminal numbers differ between the backplane and the DIN-rail mounting models.

The analogue input models covered by this manual are:

Module type	Number of channels	Safe area connection
MTL4541A and 5541A	1	Current source
MTL4541AS and 5541AS	1	Current sink
MTL4544A and 5544A	2	Current source
MTL4544AS and 5544AS	2	Current sink

Note: To avoid repetition, further use of MTLx54xA and MTLx54xAS in this document can be understood to

include both DIN-rail and backplane models. Individual model numbers will be used only where there is a need to distinguish between them.

All the module types described in this manual have the same connectivity for the field signals, supporting

4-wire process transmitters or currents sourced in the hazardous area. The connection of the repeated current

signals into the input measurement channels for the safety logic system follows the arrangement shown in the

following diagram. When the input channels of the Safety Instrumented System (SIS) are providing power for

the loop, the 'S' variants of the isolator modules are used to 'sink' the measuring current.

In the other cases the isolator modules 'source' the measuring current that flows into a load

resistor inside the  
input card of the Safety Instrumented System.  
4SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2

2+

1-

Pwr

0V

24V

Safety Instrumented

System (SIS)

Logic Solver with 'Passive'

input

MTLx541A/

MTLx544A

(Safe area current source)

B

A

2+

1-

Pwr

0V

24V

Safety Instrumented

System (SIS)

Logic Solver with 2-wire input

A

B

Current

limiter

Output

terminal

MTL4541A,

MTL4541AS

MTL5541A, MTL5541AS

A 8 11

B 9 12

4-wire

Transmitter or

current source

Pwr

Field wiring

MTLx541AS/MTLx544AS

(Safe area current sink)

Figure 1.1 – Input and output connections

### 1.3 Product build revisions covered by this manual

The information provided in this manual is valid for the product build revisions listed in the following table:

Model Type Product build revision covered by this manual

MTL4541A Up to and including 08

MTL4541AS Up to and including 08

MTL5541A Up to and including 08

MTL5541AS Up to and including 08

MTL4544A Up to and including 08

MTL4544AS Up to and including 08

MTL5544A Up to and including 08

MTL5544AS Up to and including 08

The product build revision is identified by the field 'CC' in the module Product Identification Number that

appears at the bottom left-hand corner of the side label:

The CC field immediately precedes the 7-digit Serial Number field, DDDDDDD. Example:

5SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2

### 2 System configuration

An MTLx54x module may be used in single-channel (1oo1) safety functions up to SIL 2. The worked example

in this manual is for a SIL 2 application.

The figure below shows the system configuration and specifies detailed interfaces to the safety-related and

non safety-related system components. It does not aim to show all details of the internal module structure,

but is intended to support understanding for the application.

#### Figure 2 – System Configuration

The MTLx54xA/MTLx54xAS modules are designed to receive an active 4-20mA signal from separately

powered process transmitters in the hazardous area and to repeat the current flowing in the field loop to the

safe-area load. The shaded area indicates the safety-related system connection, while the power supply con-

nections are not safety-related. The term 'Logic Solver' has been used to denote the safety system performing

the monitoring function of the process loop variable.

Note: When using the MTLx544A/MTLx544AS dual-channel modules, it is not appropriate for both channels

to be used in the same loop, or the same safety function, as this creates concerns regarding common-cause

failures. Consideration must also be given to the effect of common-cause failures when both loops of a dual-

channel module are used for different safety functions.

Hazardous area Safe area

Logic Solver

(Safety  
related)

Logic Solver

(Safety  
related)

Power supply

(Not safety  
related)

MTL5544A/MTL5544AS (2-channel version) shown.

MTL5541A/MTL5541AS (single-channel version) omits Ch 2.

20 - 35V dc

6SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2

### 2.1 Associated System Components

There are many parallels between the loop components that must be assessed for intrinsic safety as well as functional safety. In both situations the contribution of each part is considered in relation to the whole.

The MTLx54xA/MTLx54xAS modules are components in the signal path between safety-related process transmitters and safety-related control systems. The transmitter or other field device must be suitable for the process and have been assessed and independently verified for use in functional safety applications. The field instrument and Analogue input card of the Logic Solver shall have a normal operating range of 4-20mA but be capable of working over an extended range of 3 to 22mA for under- and over-range. The Logic Solver shall have the ability to detect and annunciate input currents higher than the threshold of 21mA and lower than the threshold of 3.6mA to determine out-of-range conditions.

Note that the transmission of HART data is not considered as part of the safety function and is excluded from this analysis. However, for HART data communication to take place, the input impedance of the receiving equipment must be at least 240R.

### 3 Selection of product and implications

The safe area output signal from the MTLx541A/AS and MTLx544A/AS modules is within the operating range of 4-20mA under normal conditions. If the field wiring to the transmitter or connection between the isolator and logic solver is open-circuit then the loop current will fall to less than 3.6mA and close to zero. If the field wiring connection between the transmitter and isolator is short-circuited, the loop current will also fall to below 3.6mA.

For module types MTLx541A and MTLx544A that source the 4-20mA signal in the safe area circuit, then the current seen by the logic solver will fall to less than 3.6mA and close to zero if the connection between the isolator and logic solver is shorted.

For module types MTLx541AS and MTLx544AS that sink the 4-20mA signal in the safe area circuit, then the current seen by the logic solver will rise to a value greater than 21mA if the connection between the isolator and logic solver is shorted.

In both cases, the fault condition must be detected by the logic solver in Functional Safety applications. This should also include the detection of power supply failures which cause the output of the isolator to fall to zero mA.

#### 4 Assessment of Functional Safety

##### 4.1 Hardware Safety Integrity

The hardware assessment shows that MTLx541A/MTLx541AS and MTLx544A/MTLx544AS modules:

- have a hardware fault tolerance (HFT) of 0
- are classified as Type A devices (“non-complex” component with well-defined failure modes)
- have no internal diagnostic elements

The failure rates of these modules at an ambient temperature of 45°C are as follows:

Failure mode

Failure rate (FIT)\*

MTL4541A

MTL5541A

MTL4541AS

MTL5541AS

MTL4544A

MTL5544A

MTL4544AS

MTL5544AS

Output current >21mA (upscale) 3 3 3 14

Output current <3.6mA (downscale) 224 224 264 253

Output current within range but >2% in error 42 42 49 49

Output current correct within ±2% 73 73 80 81

\*(FITs means failures per 10<sup>9</sup> hours or failures per thousand million hours)

• Reliability data for this analysis is taken from IEC TR 62380:2004 Reliability Data Handbook.

• Failure mode distributions are taken principally from IEC 62061:2005 Safety of Machinery.

• Stated failure rates for dual-channel modules apply to a single channel.

It is assumed that the module is powered from a nominal 24V dc supply and operating at a maximum ambient

temperature of 45°C.

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#### 4.2 Systematic Safety Integrity

The MTLx54x modules have a systematic safety integrity measure of SC 2. This has been established using

compliance Route 1S, as described in IEC 61508-2: 2010, section 7.4.2.2 c.

#### 4.3 SIL Capability

Considering both the hardware safety integrity and the systematic capability, this allows the modules to be

used in safety functions up to SIL 2 in a simplex architecture (HFT=0), provided SFF ≥60% is the case for the

application. The hardware safety integrity assessment has been conducted according to compliance Route 1H,

as described in IEC 61508-2:2010, section 7.4.4. (See example below).

Note:

- Independent of hardware architecture and systematic capability considerations, the hardware probability of failure for the entire safety function needs to be calculated for the application to ensure the required PFH (for a high or continuous demand safety function) or PFDAVG (for a low demand safety function) for the SIL is met.

#### 4.4 Example of use in a safety function

In this example, the application context is assumed to be:

- the safety function is to repeat current within ±2%
- the logic solver will diagnose currents above 21mA and below 3.6mA as faults and take appropriate action

The failure modes shown above can then be defined as:

Failure mode Category

Output current >21mA (upscale) Dangerous detected, dd

Output current <3.6mA (downscale) Dangerous detected, dd

Output current within range but >2% in error Dangerous undetected, du

Output current correct within ±2% No effect, ne\*

The failure rates of the MTL4541A and MTL5541A for these categories are then (FITs):

Model sd su dd du ne\*

MTL4541A or MTL5541A 0 0 227 42 73

In this example, the safe failure fraction (SFF) is 84.4%.

\* ne is not used in the calculation of SFF. Defining the “output current correct within ±2%” failure mode as

ne represents a conservative approach to the calculation of SFF. Interpreting this failure mode as su (safe,

undetected) may also be considered and yields an SFF value of 87.7%.

Accordingly, the SFF of all module types described in this manual, when used in the same application,

are as follows:

Model sd su dd du ne SFF

MTL4541A, MTL5541A, MTL4541AS,

MTL5541AS 0 0 227 42 73 84.4%

MTL4544A, MTL5544A 0 0 267 49 80 84.5%

MTL5544AS, MTL5544AS 0 0 267 49 81 84.5%

8SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2

#### 4.5 EMC

The MTL4500 and MTL5500 modules are designed for operation in normal industrial electromagnetic environment but, to support good practice, modules should be mounted without being subjected to undue conducted or radiated interference, see Appendix A for applicable standards and levels.

#### 4.6 Environmental

The MTL4500 and MTL5500 modules operate over the temperature range from -20°C to +60°C, and at up to 95% non-condensing relative humidity.

The modules are intended to be mounted in a normal industrial environment without excessive vibration, as specified for the MTL4500 & MTL5500 product ranges. See Appendix A for applicable standards and levels. Continued reliable operation will be assured if the exposure to temperature and vibration are within the values given in the specification.

#### 5 Installation

There are two particular aspects of safety that must be considered when installing the MTL4500 or MTL5500 modules and these are:

- Functional safety
- Intrinsic safety

Reference must be made to the relevant sections within the instruction manual for MTL4500 range (INM4500) or MTL5500 range (INM5500) which contain basic guides for the installation of the interface equipment to meet the requirements of intrinsic safety. In many countries there are specific codes of practice, together with industry guidelines, which must also be adhered to.

Provided that these installation requirements are followed then there are no additional factors to meet the needs of applying the products for functional safety use.

To guard against the effects of dust and water the modules should be mounted in an enclosure providing at least IP54 protection degree, or the location of mounting should provide equivalent protection such as inside an

equipment cabinet.

In applications using MTL4500 range, where the environment has a high humidity, the mounting backplanes

should be specified to include conformal coating.

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## 6 Maintenance

To follow the guidelines pertaining to operation and maintenance of intrinsically safe equipment in a hazardous area, yearly periodic audits of the installation are required by the various codes of practice.

In addition, proof-

testing of the loop operation to conform with functional safety requirements should be carried out at the

intervals determined by safety case assessment.

Proof testing must be carried out according to the application requirements, but it is recommended that this be

carried out at least once every three years.

Refer to Appendix B for the proof testing procedure of the MTLx541A/AS and MTLx544A/AS modules.

Note that there may also be specific requirements laid down in the E/E/PE operational maintenance procedure

for the complete installation.

If an MTLx541A/AS and MTLx544A/AS module is found to be faulty during commissioning or during the normal

lifetime of the product, then such failures should be reported to the local MTL office. When appropriate, a Cus-

tomers Incident Report (CIR) will be notified by Eaton to enable the return of the unit to the factory for analysis.

If the unit is within the warranty period then a replacement unit will be sent.

Consideration should be given to the service lifetime for a device of this type, which is in the region of ten

years. Operating an MTLx541A/AS and MTLx544A/AS module for longer than this period could invalidate the

functional safety analysis, meaning that the overall safety function no longer meets its target SIL. If high failure

rates of the MTL modules are detected, indicating that they have entered the 'end of life phase' of their service

life, then they should be replaced promptly.

## 7 Appendices

### 7.1 Appendix A: Summary of applicable standards

This annex lists all standards referred to in the previous sections of this document:

IEC 61508:2010 Functional safety of electrical/electronic/programmable electronic safety-related systems. Parts 1 and 2 as relevant

EN 61131-2:2003 Programmable controllers – Part 2: Equipment requirement and tests (EMC requirements)

EN 61326-1:2013 Electrical equipment for measurement, control and laboratory use – EMC requirements. (Criterion A)

IEC 61326-3-1:2017 Electrical equipment for measurement, control and laboratory use – EMC requirements – Part 3-1: Immunity requirements for equipment performing or intended to perform safety related functions (functional safety) – General industrial applications. (Criterion FS)

NE21:2007 Electromagnetic Compatibility of Industrial Process and Laboratory Control Equipment. (Criterion A)

Lloyds Register Type

Approval System: 2015, Test

Specification Number 1.

Specifically vibration: 1.0mm displacement @ 5 to 13.2Hz and

EN 60068-2-27 Environmental testing. Test Ea and guidance. Shock. (Criterion FS)

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7.2 Appendix B: Proof Test Procedure, MTLx541A/AS, MTLx544A/AS Modules

Confirmation, through testing, that a safety function will operate as designed, is a necessary periodic activity to ensure that the probability of failure upon demand (PFDavg) is maintained.

In some applications, the user may prefer to conduct a proof test on the overall safety instrumented function without dismantling or disconnecting the individual instrumentation components, in order to avoid disturbing the integrity of the installation.

However, where it is deemed desirable to perform proof testing on the MTL modules individually, the following procedure may be used. Proof tests of the other components of the loop must then be conducted in accordance with their manufacturers' instructions, to maintain the integrity of the overall safety function.

Alternative proof tests may be devised and applied, provided they give a similar level of test coverage that is appropriate to the safety function.

The tests described here - see Figure 7.1 - compare the output current of the MTL isolator with the input current (A1) over the required range of operation, and measure the "error current" i.e. the difference between the two - as indicated on A2. The tests should be employed per channel, as appropriate.

Figure 7.1 - Basic test arrangement

Ammeter A2 must be capable of measuring currents of either polarity. If it is not an auto-ranging instrument, set it to a high range before switch on, and then adjust sensitivity to obtain the required reading.

Proof Test Procedure

Test sequence:

1. System - Normal operation test
2. Input /Output characteristic functional safety test
3. System - Normal operation test

-

-

-

-

-

-

-

-

-

-

-

Modules types MTL4541A, MTL4544A,  
MTL5541A, MTL5544A  
Modules types MTL4541AS, MTL4544AS,  
MTL5541AS, MTL5544AS  
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1 System - Normal operation test

Make sure that the module to be tested is operating normally in the target system, without errors and in an

energised mode. If the module is in a faulty or de-energised loop, restore normal fault-free

and energised operation before testing.

**2 Input/Output characteristic functional safety test**

Observe normal anti-static precautions when handling equipment during device testing.

Remove the unit from the target system and connect it as shown in Figure 7.2. This figure shows the arrangement for the MTLx541A/AS single-channel modules; for equivalent connections for the MTLx544A/AS dual-channel modules, refer to the relevant product data sheets. Note that it is acceptable to leave the unit in the target system but only after ensuring that the all the hazardous area input and safe area output terminals have been disconnected from the system and are available for test. Alternatively, for the backplane-mounted MTL4500 range modules, a separate backplane can be used to provide access to the power and output connections. Note that the combination of the 24V power supply and variable resistor RV1 in the hazardous area connection can be provided by a suitable industrial current simulator, which is likely to be more readily available. Also, the 250R resistor does not need to be a precision type; any value in the range 200-300R is acceptable would suffice, such as a standard value of 240R.

Where a second power supply is introduced for testing the MTLx541AS or MTLx544AS module variants, note that both power supplies must be floating and not share a common 0V connection. During testing, a 24V nominal system power supply in the range 20.0 to 35.0V should be connected between terminals 13 and 14 (+ve to terminal 14).

Figure 7.2 - Connections for testing the MTL5541A/AS and MTL4541A/AS modules

1	2	3	4	5	6
Ch1					
i/p					
Ch2					
i/p					
Ch2					
o/p					
Ch1					
o/p					
MTL5541A 13(-)					
14(+)					
7	8	9	10	11	12
V	VS				
Power					

supply  
 +  
 MTL5501-SR 13(-)  
 14(+)  
 V S  
 + - + - + -  
 + -  
 + -  
 V  
 +  
 Ch1  
 i/p  
 Ch2  
 i/p  
 Insert 250R and 24V  
 supply for MTLx54xS  
 modules, otherwise use  
 direct link to o/p(+)  
 14 13 12 11 10 9 8 7  
 MTL4541A  
 1 2 3 4 5 6  
 Ch1  
 i/p  
 Ch2  
 i/p  
 Ch2  
 o/p  
 Ch1  
 o/p  
 + -  
 +  
 -  
 +  
 -  
 +  
 -  
 +  
 -  
 A 1  
 A1  
 250RRV 1  
 +  
 250R  
 24V dc

24V dc

--

+

-

+

-

A1

A 1

250RRV 1

+

250R

24V dc

24V dc

--

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Channel 1

Channel 2

Measurements

Make the following measurements. It is recommended to record the results in a table such as that shown on the next page.

1. Adjust resistor RV1 to vary the loop current (measured by Ammeter A1) through the range 4 to 20mA.

(Tests 1 - 5 in table)

2. The measured current imbalance (measured by Ammeter A2) over this range should not exceed  $\pm 50\mu\text{A}$ .

3. Adjust RV1 to vary the current (A1) to 3.5mA and then 21.5mA (tests 6 & 7 in table).

4. The measured current imbalance (A2) at these currents should not exceed  $\pm 200\mu\text{A}$ .

5. Record the supply voltage Vs.

If appropriate, repeat these measurements for Channel 2.

3 System - Normal operation test

Disconnect the test setup from the unit and reconnect the original system configuration.

Make sure that the

tested unit operates normally in the target system, as before, without errors and in energised mode.

Date: \_\_\_\_/\_\_\_\_/\_\_\_\_ Supply voltage Vs: \_\_\_\_\_ V dc

Module type: \_\_\_\_\_ Serial No: \_\_\_\_\_

Test # Description Actual Target

1 Current imbalance (A2 ) at loop current (A1) = 4mA  $< \pm 50\mu\text{A}$

2 Current imbalance (A2 ) at loop current (A1) = 8mA  $< \pm 50\mu\text{A}$

3 Current imbalance (A2 ) at loop current (A1) = 12mA  $< \pm 50\mu\text{A}$

4 Current imbalance (A2 ) at loop current (A1) = 16mA  $< \pm 50\mu\text{A}$

5 Current imbalance (A2 ) at loop current (A1) = 20mA  $< \pm 50\mu\text{A}$

6 Current imbalance (A2 ) at loop current (A1) = 3.5mA  $< \pm 200\mu\text{A}$

7 Current imbalance (A2 ) at loop current (A1) = 21.5mA <±200µA

Test Step# Description Actual Target

1 Current imbalance (A2 ) at loop current (A1) = 4mA <±50µA

2 Current imbalance (A2 ) at loop current (A1) = 8mA <±50µA

3 Current imbalance (A2 ) at loop current (A1) = 12mA <±50µA

4 Current imbalance (A2 ) at loop current (A1) = 16mA <±50µA

5 Current imbalance (A2 ) at loop current (A1) = 20mA <±50µA

6 Current imbalance (A2 ) at loop current (A1) = 3.5mA <±200µA

7 Current imbalance (A2 ) at loop current (A1) = 21.5mA <±200µA

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The given data is only intended as a product description and should not be regarded as a legal warranty of properties or guarantee. In the interest of further technical developments, we reserve the right to make design changes.

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E-mail: [mtl-us-info@eaton.com](mailto:mtl-us-info@eaton.com) MTL4500/MTL5500 range

Analogue Input Modules with passive input for

4-wire separately powered transmitters

MTL4541A, MTL4541AS, MTL5541A, MTL5541AS,

MTL4544A, MTL4544AS, MTL5544A, MTL5544AS

April 2024

SM4541A/AS, 5541A/AS,

4544A/AS, 5544A/AS rev 2

Safety manual

MTL intrinsic safety solutions

## FUNCTIONAL SAFETY MANAGEMENT

These products are for use as elements within a Safety System conforming to the requirements of IEC

61508:2010 and enable a Safety Integrity Level of up to SIL 2 to be achieved for the instrument loop in a simplex architecture.

Eaton Electric Ltd, Luton is a certified Functional Safety Management company meeting the requirements

of IEC61508:2010 Part 1, Clause 6.

\*

\* Subject to special conditions for detection of out-of-range signal currents. Refer to content of this manual for details.

SIL

IEC 61508:2010

2

2SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2

This manual supports the application of the products in functional-safety related loops. It must be used

in conjunction with other supporting documents to achieve correct installation, commissioning and

operation. Specifically, the data sheet, instruction manual and applicable certificates for the particular

product should be consulted, all of which are available on the MTL web site.

In the interest of further technical developments, Eaton reserve the right to make design changes.

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Analogue Input Modules with passive input for 4-wire transmitters	
Hardware Fault Tolerance (HFT) †	
Module type 0, 1	
MTL4541A,	
MTL4541AS,	
MTL5541A,	
MTL5541AS,	
MTL4544A,	
MTL4544AS,	
MTL5544A,	
MTL5544AS	
† These modules have an inherent fault tolerance of 0.	
SIL	
IEC 61508:2010	
2	
3SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2	
1 INTRODUCTION	
1.1 Application and function	
The Analogue Input module types MTLx541A/MTLx541AS (single channel) and MTLx544A/MTLx544AS	
(dual channel) are intrinsic safety isolators that interface with process measurement transmitters located in	

a hazardous area of a process plant. They are also designed and assessed according to IEC 61508 for use in safety instrumented systems up to SIL 2.

The MTLx541A provides an input for a separately-powered 4/20mA transmitter located in a hazardous area, and repeats the transmitter current into a load in the safe area. The MTLx544A supports two identical channels for use with two separate transmitters. The MTLx541AS and MTLx544AS versions act as a current sink for the safe area connection rather than driving the current into the load.

All the modules allow bi-directional transmission of HART communication signals superimposed on the 4/20mA loop current, so that the transmitter can be interrogated either from the operator station or by a hand-held communicator (HHC).

There are no configuration switches or operator controls to be set on the modules. These modules are members of the MTL4500 and MTL5500 range of products.

## 1.2 Variant Description

Functionally the MTL4500 and MTL5500 range of modules are the same but differ in the following way:

- the MTL4500 modules are designed for backplane mounted applications
- the MTL5500 modules are designed for DIN-rail mounting.

In both models the hazardous area field-wiring connections (terminals 1,2, and optionally 4,5) are made through the removable blue connectors, but the safe area and power connections for the MTL454xA/MTL454xAS modules are made through the connector on the base, while the MTL554xA/MTL554xAS modules use the removable grey connectors on the top and side of the module.

Note that the safe-area connection terminal numbers differ between the backplane and the DIN-rail mounting models.

The analogue input models covered by this manual are:

Module type	Number of channels	Safe area connection
MTL4541A and 5541A	1	Current source
MTL4541AS and 5541AS	1	Current sink
MTL4544A and 5544A	2	Current source
MTL4544AS and 5544AS	2	Current sink

Note: To avoid repetition, further use of MTLx54xA and MTLx54xAS in this document can be understood to

include both DIN-rail and backplane models. Individual model numbers will be used only where there is a need to distinguish between them.

All the module types described in this manual have the same connectivity for the field signals, supporting 4-wire process transmitters or currents sourced in the hazardous area. The connection of the repeated current signals into the input measurement channels for the safety logic system follows the arrangement shown in the following diagram. When the input channels of the Safety Instrumented System (SIS) are providing power for the loop, the 'S' variants of the isolator modules are used to 'sink' the measuring current. In the other cases the isolator modules 'source' the measuring current that flows into a load resistor inside the input card of the Safety Instrumented System.

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2+

1-

Pwr

0V

24V

Safety Instrumented

System (SIS)

Logic Solver with 'Passive'

input

MTLx541A/

MTLx544A

(Safe area current source)

B

A

2+

1-

Pwr

0V

24V

Safety Instrumented

System (SIS)

Logic Solver with 2-wire input

A

B

Current

limiter

Output

terminal

MTL4541A,

MTL4541AS

MTL5541A, MTL5541AS

A 8 11

B 9 12

4-wire

Transmitter or  
current source

Pwr

Field wiring

MTLx541AS/MTLx544AS

(Safe area current sink)

Figure 1.1 – Input and output connections

1.3 Product build revisions covered by this manual

The information provided in this manual is valid for the product build revisions listed in the following table:

Model Type Product build revision covered by this manual

MTL4541A Up to and including 08

MTL4541AS Up to and including 08

MTL5541A Up to and including 08

MTL5541AS Up to and including 08

MTL4544A Up to and including 08

MTL4544AS Up to and including 08

MTL5544A Up to and including 08

MTL5544AS Up to and including 08

The product build revision is identified by the field 'CC' in the module Product Identification Number that

appears at the bottom left-hand corner of the side label:

The CC field immediately precedes the 7-digit Serial Number field, DDDDDDD. Example:

5SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2

2 System configuration

An MTLx54x module may be used in single-channel (1oo1) safety functions up to SIL 2. The worked example

in this manual is for a SIL 2 application.

The figure below shows the system configuration and specifies detailed interfaces to the safety-related and

non safety-related system components. It does not aim to show all details of the internal module structure,

but is intended to support understanding for the application.

Figure 2 – System Configuration

The MTLx54xA/MTLx54xAS modules are designed to receive an active 4-20mA signal from separately

powered process transmitters in the hazardous area and to repeat the current flowing in the field loop to the

safe-area load. The shaded area indicates the safety-related system connection, while the power supply con-

nections are not safety-related. The term 'Logic Solver' has been used to denote the safety

system performing the monitoring function of the process loop variable.

Note: When using the MTLx544A/MTLx544AS dual-channel modules, it is not appropriate for both channels to be used in the same loop, or the same safety function, as this creates concerns regarding common-cause failures. Consideration must also be given to the effect of common-cause failures when both loops of a dual-channel module are used for different safety functions.

Hazardous area Safe area

Logic Solver  
(Safety related)

Logic Solver  
(Safety related)

Power supply  
(Not safety related)

MTL5544A/MTL5544AS (2-channel version) shown.  
MTL5541A/MTL5541AS (single-channel version) omits Ch 2.

20 - 35V dc

6SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2

## 2.1 Associated System Components

There are many parallels between the loop components that must be assessed for intrinsic safety as well as functional safety. In both situations the contribution of each part is considered in relation to the whole.

The MTLx54xAS modules are components in the signal path between safety-related process transmitters and safety-related control systems. The transmitter or other field device must be suitable for the process and have been assessed and independently verified for use in functional safety applications. The field instrument and Analogue input card of the Logic Solver shall have a normal operating range of 4-20mA but be capable of working over an extended range of 3 to 22mA for under- and over-range. The Logic Solver shall have the ability to detect and annunciate input currents higher than the threshold of 21mA and lower than the threshold of 3.6mA to determine out-of-range conditions.

Note that the transmission of HART data is not considered as part of the safety function and is excluded from this analysis. However, for HART data communication to take place, the input impedance of the receiving equip-

ment must be at least 240R.

### 3 Selection of product and implications

The safe area output signal from the MTLx541A/AS and MTLx544A/AS modules is within the operating range of

4-20mA under normal conditions. If the field wiring to the transmitter or connection

between the isolator and logic

solver is open-circuit then the loop current will fall to less than 3.6mA and close to zero. If

the field wiring connection

between the transmitter and isolator is short-circuited, the loop current will also fall to below 3.6mA.

For module types MTLx541A and MTLx544A that source the 4-20mA signal in the safe area circuit, then the current

seen by the logic solver will fall to less than 3.6mA and close to zero if the connection

between the isolator and logic

solver is shorted.

For module types MTLx541AS and MTLx544AS that sink the 4-20mA signal in the safe area circuit, then the current

seen by the logic solver will rise to a value greater than 21mA if the connection between the

isolator and logic solver

is shorted.

In both cases, the fault condition must be detected by the logic solver in Functional Safety applications. This should

also include the detection of power supply failures which cause the output of the isolator to fall to zero mA.

### 4 Assessment of Functional Safety

#### 4.1 Hardware Safety Integrity

The hardware assessment shows that MTLx541A/MTLx541AS and MTLx544A/MTLx544AS modules:

- have a hardware fault tolerance (HFT) of 0
- are classified as Type A devices ("non-complex" component with well-defined failure modes)
- have no internal diagnostic elements

The failure rates of these modules at an ambient temperature of 45°C are as follows:

Failure mode

Failure rate (FIT)\*

MTL4541A

MTL5541A

MTL4541AS

MTL5541AS

MTL4544A

MTL5544A

MTL4544AS

MTL5544AS

Output current >21mA (upscale) 3 3 3 14

Output current <3.6mA (downscale) 224 224 264 253

Output current within range but >2% in error 42 42 49 49

Output current correct within  $\pm 2\%$  73 73 80 81

\*(FITs means failures per 10<sup>9</sup> hours or failures per thousand million hours)

- Reliability data for this analysis is taken from IEC TR 62380:2004 Reliability Data Handbook.
- Failure mode distributions are taken principally from IEC 62061:2005 Safety of Machinery.
- Stated failure rates for dual-channel modules apply to a single channel.

It is assumed that the module is powered from a nominal 24V dc supply and operating at a maximum ambient temperature of 45°C.

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#### 4.2 Systematic Safety Integrity

The MTLx54x modules have a systematic safety integrity measure of SC 2. This has been established using

compliance Route 1S, as described in IEC 61508-2: 2010, section 7.4.2.2 c.

#### 4.3 SIL Capability

Considering both the hardware safety integrity and the systematic capability, this allows the modules to be

used in safety functions up to SIL 2 in a simplex architecture (HFT=0), provided SFF  $\geq 60\%$  is the case for the

application. The hardware safety integrity assessment has been conducted according to compliance Route 1H,

as described in IEC 61508-2:2010, section 7.4.4. (See example below).

Note:

- Independent of hardware architecture and systematic capability considerations, the hardware probability of failure for the entire safety function needs to be calculated for the application to ensure the required PFH (for a high or continuous demand safety function) or PFD<sub>AVG</sub> (for a low demand safety function) for the SIL is met.

#### 4.4 Example of use in a safety function

In this example, the application context is assumed to be:

- the safety function is to repeat current within  $\pm 2\%$
- the logic solver will diagnose currents above 21mA and below 3.6mA as faults and take appropriate action

The failure modes shown above can then be defined as:

Failure mode Category

Output current >21mA (upscale) Dangerous detected, dd

Output current <3.6mA (downscale) Dangerous detected, dd

Output current within range but >2% in error Dangerous undetected, du

Output current correct within  $\pm 2\%$  No effect, ne\*

The failure rates of the MTL4541A and MTL5541A for these categories are then (FITs):

Model sd su dd du ne\*

MTL4541A or MTL5541A 0 0 227 42 73

In this example, the safe failure fraction (SFF) is 84.4%.

\* ne is not used in the calculation of SFF. Defining the “output current correct within  $\pm 2\%$ ” failure mode as

ne represents a conservative approach to the calculation of SFF. Interpreting this failure mode as su (safe,

undetected) may also be considered and yields an SFF value of 87.7%.

Accordingly, the SFF of all module types described in this manual, when used in the same application,

are as follows:

Model sd su dd du ne SFF

MTL4541A, MTL5541A, MTL4541AS,

MTL5541AS 0 0 227 42 73 84.4%

MTL4544A, MTL5544A 0 0 267 49 80 84.5%

MTL5544AS, MTL5544AS 0 0 267 49 81 84.5%

8SM4541A/AS, 5541A/AS, 4544A/AS, 5544A/AS rev 2

#### 4.5 EMC

The MTL4500 and MTL5500 modules are designed for operation in normal industrial electromagnetic environ-

ment but, to support good practice, modules should be mounted without being subjected to undue conducted

or radiated interference, see Appendix A for applicable standards and levels.

#### 4.6 Environmental

The MTL4500 and MTL5500 modules operate over the temperature range from  $-20^{\circ}\text{C}$  to  $+60^{\circ}\text{C}$ , and at up to

95% non-condensing relative humidity.

The modules are intended to be mounted in a normal industrial environment without excessive vibration, as

specified for the MTL4500 & MTL5500 product ranges. See Appendix A for applicable standards and levels.

Continued reliable operation will be assured if the exposure to temperature and vibration are within the values

given in the specification.

#### 5 Installation

There are two particular aspects of safety that must be considered when installing the MTL4500 or MTL5500

modules and these are:

- Functional safety
- Intrinsic safety

Reference must be made to the relevant sections within the instruction manual for MTL4500 range (INM4500)

or MTL5500 range (INM5500) which contain basic guides for the installation of the interface equipment to

meet the requirements of intrinsic safety. In many countries there are specific codes of practice, together with industry guidelines, which must also be adhered to.

Provided that these installation requirements are followed then there are no additional factors to meet the needs of applying the products for functional safety use.

To guard against the effects of dust and water the modules should be mounted in an enclosure providing at least IP54 protection degree, or the location of mounting should provide equivalent protection such as inside an equipment cabinet.

In applications using MTL4500 range, where the environment has a high humidity, the mounting backplanes should be specified to include conformal coating.

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## 6 Maintenance

To follow the guidelines pertaining to operation and maintenance of intrinsically safe equipment in a hazardous

area, yearly periodic audits of the installation are required by the various codes of practice.

In addition, proof-

testing of the loop operation to conform with functional safety requirements should be carried out at the

intervals determined by safety case assessment.

Proof testing must be carried out according to the application requirements, but it is recommended that this be

carried out at least once every three years.

Refer to Appendix B for the proof testing procedure of the MTLx541A/AS and MTLx544A/AS modules.

Note that there may also be specific requirements laid down in the E/E/PE operational maintenance procedure for the complete installation.

If an MTLx541A/AS and MTLx544A/AS module is found to be faulty during commissioning or during the normal

lifetime of the product, then such failures should be reported to the local MTL office. When appropriate, a Cus-

tomers Incident Report (CIR) will be notified by Eaton to enable the return of the unit to the factory for analysis.

If the unit is within the warranty period then a replacement unit will be sent.

Consideration should be given to the service lifetime for a device of this type, which is in the region of ten

years. Operating an MTLx541A/AS and MTLx544A/AS module for longer than this period could invalidate the

functional safety analysis, meaning that the overall safety function no longer meets its target SIL. If high failure

rates of the MTL modules are detected, indicating that they have entered the 'end of life phase' of their service life, then they should be replaced promptly.

## 7 Appendices

### 7.1 Appendix A: Summary of applicable standards

This annex lists all standards referred to in the previous sections of this document:

IEC 61508:2010 Functional safety of electrical/electronic/programmable electronic safety-related systems. Parts 1 and 2 as relevant

EN 61131-2:2003 Programmable controllers – Part 2: Equipment requirement and tests (EMC requirements)

EN 61326-1:2013 Electrical equipment for measurement, control and laboratory use – EMC requirements. (Criterion A)

IEC 61326-3-1:2017 Electrical equipment for measurement, control and laboratory use – EMC requirements – Part 3-1: Immunity requirements for equipment

performing or intended to perform safety related functions

(functional safety) – General industrial applications. (Criterion FS)

NE21:2007 Electromagnetic Compatibility of Industrial Process and Laboratory Control Equipment. (Criterion A)

Lloyds Register Type

Approval System: 2015, Test

Specification Number 1.

Specifically vibration: 1.0mm displacement @ 5 to 13.2Hz and

EN 60068-2-27 Environmental testing. Test Ea and guidance. Shock. (Criterion FS)

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### 7.2 Appendix B: Proof Test Procedure, MTLx541A/AS, MTLx544A/AS Modules

Confirmation, through testing, that a safety function will operate as designed, is a necessary periodic activity to

ensure that the probability of failure upon demand (PFDavg) is maintained.

In some applications, the user may prefer to conduct a proof test on the overall safety instrumented function

without dismantling or disconnecting the individual instrumentation components, in order to avoid disturbing

the integrity of the installation.

However, where it is deemed desirable to perform proof testing on the MTL modules individually, the

following procedure may be used. Proof tests of the other components of the loop must then be conducted

in accordance with their manufacturers' instructions, to maintain the integrity of the overall safety function.

Alternative proof tests may be devised and applied, provided they give a similar level of test coverage that is

appropriate to the safety function.

The tests described here - see Figure 7.1 - compare the output current of the MTL isolator with the input current

(A1) over the required range of operation, and measure the “error current” i.e. the difference between the two -  
as indicated on A2. The tests should be employed per channel, as appropriate.

Figure 7.1 - Basic test arrangement

Ammeter A2 must be capable of measuring currents of either polarity. If it is not an auto-ranging instrument,  
set it to a high range before switch on, and then adjust sensitivity to obtain the required reading.

Proof Test Procedure

Test sequence:

1. System - Normal operation test
2. Input /Output characteristic functional safety test
3. System - Normal operation test

-

-

-

-

-

-

-

-

-

-

-

Modules types MTL4541A, MTL4544A,  
MTL5541A, MTL5544A

Modules types MTL4541AS, MTL4544AS,  
MTL5541AS, MTL5544AS

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1 System - Normal operation test

Make sure that the module to be tested is operating normally in the target system, without errors and in an

energised mode. If the module is in a faulty or de-energised loop, restore normal fault-free and energised

operation before testing.

2 Input/Output characteristic functional safety test

Observe normal anti-static precautions when handling equipment during device testing.

Remove the unit from

the target system and connect it as shown in Figure 7.2. This figure shows the arrangement for the MTLx541A/

AS single-channel modules; for equivalent connections for the MTLx544A/AS dual-channel modules, refer to

the relevant product data sheets. Note that it is acceptable to leave the unit in the target system but only after

ensuring that the all the hazardous area input and safe area output terminals have been disconnected from the

system and are available for test. Alternatively, for the backplane-mounted MTL4500 range modules, a separate

backplane can be used to provide access to the power and output connections.

Note that the combination of the 24V power supply and variable resistor RV1 in the hazardous area connection

can be provided by a suitable industrial current simulator, which is likely to be more readily available. Also,

the 250R resistor does not need to be a precision type; any value in the range 200-300R is acceptable would

suffice, such as a standard value of 240R.

Where a second power supply is introduced for testing the MTLx541AS or MTLx544AS module variants, note

that both power supplies must be floating and not share a common 0V connection.

During testing, a 24V nominal system power supply in the range 20.0 to 35.0V should be connected between

terminals 13 and 14 (+ve to terminal 14).

Figure 7.2 - Connections for testing the MTL5541A/AS and MTL4541A/AS modules

1 2 3 4 5 6

Ch1

i/p

Ch2

i/p  
 Ch2  
 o/p  
 Ch1  
 o/p  
 MTL5541A 13(-)  
 14(+)  
 7 8 9 10 11 12  
 V VS  
 Power  
 supply  
 +  
 MTL5501-SR 13(-)  
 14(+)  
 V S  
 + - + - + -  
 + -  
 + -  
 V  
 +  
 Ch1  
 i/p  
 Ch2  
 i/p  
 Insert 250R and 24V  
 supply for MTLx54xS  
 modules, otherwise use  
 direct link to o/p(+)  
 14 13 12 11 10 9 8 7  
 MTL4541A  
 1 2 3 4 5 6  
 Ch1  
 i/p  
 Ch2  
 i/p  
 Ch2  
 o/p  
 Ch1  
 o/p  
 + -  
 +  
 -  
 +  
 -

+

—

+

—

A 1

A1

250RRV 1

+

250R

24V dc

24V dc

— —

+

—

+

—

A1

A 1

250RRV 1

+

250R

24V dc

24V dc

— —

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Channel 1

Channel 2

Measurements

Make the following measurements. It is recommended to record the results in a table such as that shown on the next page.

1. Adjust resistor RV1 to vary the loop current (measured by Ammeter A1) through the range 4 to 20mA.

(Tests 1 - 5 in table)

2. The measured current imbalance (measured by Ammeter A2) over this range should not exceed  $\pm 50\mu\text{A}$ .

3. Adjust RV1 to vary the current (A1) to 3.5mA and then 21.5mA (tests 6 & 7 in table).

4. The measured current imbalance (A2) at these currents should not exceed  $\pm 200\mu\text{A}$ .

5. Record the supply voltage  $V_s$ .

If appropriate, repeat these measurements for Channel 2.

3 System - Normal operation test

Disconnect the test setup from the unit and reconnect the original system configuration.

Make sure that the

tested unit operates normally in the target system, as before, without errors and in

energised mode.

Date: \_\_\_\_/\_\_\_\_/\_\_\_\_ Supply voltage Vs: \_\_\_\_\_ V dc

Module type: \_\_\_\_\_ Serial No: \_\_\_\_\_

Test # Description Actual Target

- 1 Current imbalance (A2 ) at loop current (A1) = 4mA <±50µA
- 2 Current imbalance (A2 ) at loop current (A1) = 8mA <±50µA
- 3 Current imbalance (A2 ) at loop current (A1) = 12mA <±50µA
- 4 Current imbalance (A2 ) at loop current (A1) = 16mA <±50µA
- 5 Current imbalance (A2 ) at loop current (A1) = 20mA <±50µA
- 6 Current imbalance (A2 ) at loop current (A1) = 3.5mA <±200µA
- 7 Current imbalance (A2 ) at loop current (A1) = 21.5mA <±200µA

Test Step# Description Actual Target

- 1 Current imbalance (A2 ) at loop current (A1) = 4mA <±50µA
- 2 Current imbalance (A2 ) at loop current (A1) = 8mA <±50µA
- 3 Current imbalance (A2 ) at loop current (A1) = 12mA <±50µA
- 4 Current imbalance (A2 ) at loop current (A1) = 16mA <±50µA
- 5 Current imbalance (A2 ) at loop current (A1) = 20mA <±50µA
- 6 Current imbalance (A2 ) at loop current (A1) = 3.5mA <±200µA
- 7 Current imbalance (A2 ) at loop current (A1) = 21.5mA <±200µA

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DRAFT - 20 November 2014

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The given data is only intended as a product description and should not be regarded as a legal warranty of properties or guarantee. In the interest of further technical developments, we reserve the right to make design changes.

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EATON Crouse-Hinds series

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IM-ADD-UL-XWW

TM318 Iss B

ADDENDUM TO INSTALLATION INSTRUCTIONS

FOR XWW Series Washer Systems

This manual should be used in conjunction with IMI-UL-XF-XC-XP-XT,  
2400 & 1400 Series (XP, XT, XC & XF) Flame Proof Camera Housings & Pan Tilt Units  
Installation & Maintenance Instruction

This manual should be read before attempting to connect or operate the equipment.

This manual should be kept for future reference.

This equipment shall be installed in accordance with the latest local/national codes of  
practice, and standards

eg :- UL 1203 Edn. 5, CSA22.2 No30-M1986 Edn1 reaffirmed 2012, CSA C22.2 No25-1966  
reaffirmed 2014,

CSA C22.2 No 60065-03 Edn. 1, UL60065 Edn. 7,

Class I Div 1 Group B,C,D

Class II Div 1 Groups E,F,G

Class I Zone 1 IIB +Hydrogen

File No E477542

Whilst every effort has been made to ensure that all information in this document is correct  
at the time of

publication, due to our policy of continuous improvement, the company reserves the right  
to change any

information contained herein without notice.

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Amendment Record

Issue Date Details of Amendment

A 06/09/2017 First Issue as Addendum

B 20/02/2025 Wiring update

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Before Installation of the equipment ensure that:	
1 The installation instructions are read and understood	
2 The correct tools are available for use when installing	
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## 1.0 General

### 1.1 Important Safeguards and Warnings

This symbol indicates that there are important operating and maintenance instructions in the

literature accompanying this unit. Read, Keep and Follow all instructions.

Prior to installation and use of this product, observe the following warnings.

1. Installation and servicing should only be carried out by qualified service personnel and in accordance with all local/national codes of practice and standards e.g. UL1203 Edn.5, NFPA 70, no modification to the certified product allowed.
2. It is essential that provision is made for overload, short circuit and earth fault protection for this equipment. Therefore we recommend that a double pole, mains rated, miniature circuit breaker rated to the max power consumption of the unit, must be incorporated in the electrical installation of the power supply to this product if not directly connected to Eaton camera stations.
3. A readily accessible disconnection device shall be incorporated in the electrical installation wiring, to provide all pole isolation of the supply to the equipment.
4. Only use tools and replacement parts supplied or recommended by EATON.

This unit does not contain any user serviceable parts.

5. Care must be taken to ensure selection of suitable cables connecting to these units, when installed in operating temperatures above +70°C.

6. The equipment is designed to satisfy the requirements of UL60065 7th Edition 2013/07/24. CSA C22.2 No. 60065-03 2012/08/01 Safety Requirements ANNEX II of ATEX directive 94/9/EC.

7. Be aware that aggressive substances may require extra protection of the equipment to maintain its integrity and explosion protection.

8. The equipment may need additional means of protection if it is to be installed in locations where it may be exposed to excessive external stresses e.g. vibration, heat, impact and damage.

9. Any repairs or replacement parts must be done by the manufacturer or a suitably qualified repair agent.

10. Due to the weight of the units, correct planning and equipment must be used when unpacking and installing.

11. When batteries are fitted to electronic equipment they must be removed and are not to be replaced.

12. After installation, operatives must adhere to the following warning on the units label:  
WARNING: DO NOT OPEN WHEN ENERGISED OR WHEN  
AN EXPLOSIVE ATMOSPHERE IS PRESENT.  
CLEAN WITH DAMP CLOTH.

This symbol indicates that dangerous voltage constituting a risk of electric shock may be present within this unit.

EATON Installation & Maintenance Instructions IM-ADD-UL-XWW

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## 2.0 Description

The XWW Series washer pump assemblies have been developed to provide a solution for spraying a jet of water onto the window of Eaton CCTV camera housings, to aid in the cleaning of

the window, to allow unobstructed viewing by the cameras.

The units meet the rigorous requirements of Flame proof and dust-ignition-proof electrical equipment for installation and use in hazardous locations found in the onshore and offshore, oil

& gas and petro-chemical installations. The units may also be used in marine and industrial hazardous environments.

The units include a water tank for cleaning fluid and are operated by supplying a switched 24VAC

to power the internal pump.

The system can pump water up 40 feet to high mounted camera stations\*/\*\*

The Assembly is made up of an EXD certified chamber (XF26JP) that houses a pump mechanism

and a terminal strip for wiring connections, an XW10 (10 litre) or XW25 (25 litre) washer tank assembly and a Stainless steel Back Plate Mount.

All external parts, excluding washer tank and hoses, are manufactured from AISI 316L stainless steel for low maintenance and protection from corrosion.

The EXD chamber covers are fixed to the body by five (5), M6 x 16-mm stainless steel hex cap screws; all conforming to the requirements of UL 1203

The weatherproof seal of the union between the body and end covers is maintained by use of 'O' ring seals fitted in purpose made grooves.

The EXD housings features an internal sliding rail which carries terminals for pump connections as well as an allowance for pass through connections; to assist in easy connection to Eaton camera stations.

The XF26JB housings comprise a single tube section with 3 x ¾" NPT cable entries in one end.

The certification for the XF26JB housing is included within the overall certification of the 2400 & 1400 series housings and integrated pan/tilt units.

The project requirements and unit certification label must be checked by the installer before installation, to confirm that the product supplied is suitable for the intended installation zone and environment.

Manufactured in accordance with  
 UL 1203 Edn. 5, CSA22.2 No30-M1986 Edn1 reaffirmed 2012, CSA C22.2 No25-1966 reaffirmed 2014 , CSA C22.2 No 60065-03 Edn. 1, UL60065 Edn. 7,  
 \* Measured using pure water at ambient 70°F  
 \*\*Units supplied with 30 Feet of hose

EATON Installation & Maintenance Instructions IM-ADD-UL-XWW  
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## 2.1 Versions

There are two options within the series; these cover different washer tank sizes:

Part No	Description
XWW-10	10 litre 24VAC supply (including 30 feet on Antistatic Hose)
XWW-25	25 litre 24VAC supply (including 30 feet on Antistatic Hose)

## 2.2 Supplied Equipment

Contained in the package are the following items:

- XF26JB HOUSING
- Washer Tank Assembly
- Back Plate and supplied item fixings
- Installation & Maintenance Instructions

## 2.3 Recommended Tools

For installation and maintenance purposes, we recommend the following hand tools:

- Voltmeter/Ohmmeter
- Hex Allen wrench bits 5, 4, 3 & 1.5mm
- Spanners 5.5mm, 8mm, 10mm & 13mm A/F
- Screw drivers standard and Phillips head
- Pliers side cutting and long nose

#### 2.4 Recommended Spares

For Maintenance purposes, we recommend the following spares:

- PTZ Seal Kit: O Ring seal kit, spare M6 x 16 & M3 x 6 screws
- XP40 Washer Nozzle (for systems with optional washer system)
- XP26 Washer Nozzle (for systems with optional washer system)
- XF Fixed Washer Nozzle (for systems with optional washer system)
- PUMP ROTA TUBE OD7X4.8 CLEAR SILICONE

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Fig.1 XWW25 GA showing fixing points

### 3.0 Installation

In order to ensure proper wiring and system operation of all components, it is recommended

that all units and all associated control equipment be tested at your Factory before field installation is attempted.

#### 3.1 Unpacking and Handling

##### 3.1.1 Unpacking

On receipt of the units ensure that the cartons are undamaged and that the contents are all correct and complete.

After unpacking it is recommended that the packing materials are kept safe in case they are needed for returning the unit for repair or maintenance.

##### 3.1.2 Handling

The units should not be handled having direct contact with ferrous metal equipment. (see section 4.1 for details)

#### 3.2 Mounting

To prevent injury ensure the mounting surface and the selected mount can support four times

the combined weight of the complete unit, when fully filled with fluid.

Do not stand or place objects “directly under” installed system.

Secure the assemblies to a suitable surface using suitable fixings as required.

Due to the variation of possible fixing requirements fixings are not supplied. The type and size

of these fixings to be supplied by the user/installer and must be suitable for the specific installation requirements.

The Back Plate has six fixing points with slotted Ø9mm holes, see figures 1 & 2 for sizes.

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Fig.1 XWW10 GA showing fixing points

### 3.2.1 Mounting of the hose

The washer tanks are supplied with 30 feet of anti-static hose that should be connected to the

washer nozzle of an Eaton camera housing and routed as to prevent the risk of mechanical damage or to obstruct the camera housing.

The hose has an OD of 6mm and should be secure at 3 feet intervals to prevent sagging.

### 3.3 Electrical Installation

Electrical installation and servicing should only be carried out by qualified skilled personnel the class of wiring shall be marked adjacent to the terminals and in accordance with all local/national codes of practice and standards e.g. UL 1203 Edn. 5, CSA22.2 No30-M1986 reaffirmed 2014, CSA C22.2 No25-1966 reaffirmed 2014, CSA C22.2 No 60065-03 Edn. 1, UL60065 Edn. 7,

Units must be supplied with 24VAC~ Supply;  $\pm 10\%$  from a switch source.

The unit is designed to work with Eaton CCTV cameras that have a suitable, time limited, supply. If an alternative supply is used, it must have a timer function to limit on time to 15 seconds maximum.

The life of the pump will be reduced if allowed to run continuously

The units should only be powered from the specified voltage; no allowance is made for varying voltage supply.

Warning : Irreparable damage to the unit will result from the application of incorrect Power Supply Voltage

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Fig.3 Gaining access to the connection rail

Caution should be taken when removing and inserting the cable entry flange to avoid internal cable becoming snagged on corners or screws.

THE CABLE ENTRY FLANGE SHOULD NEVER BE REMOVED WHEN THE UNIT IS ENERGISED

#### 3.3.1 Electrical Installation connections

1. Always use colour-coded conductors or other identification of conductors for ease of wiring and identification of function at a later date.
2. Keep a wiring diagram with the system for later use and reference.
3. Provision is made for one, two or three cable entries, in the XF26JP housing.(Fig 1 & 2)

To maintain the certification requirements of the unit, all cables/conduits must be fitted at the entry, with certified Class / Div Flameproof, compound filled barrier glands, or conduit sealing fittings within 2" or 50mm of the enclosure.

4. The cable entry to the unit is via 3 x  $\frac{3}{4}$ " NPT thread entries.
5. A minimum of 5 fully engaged threads must be maintained for all glands and plugs.
6. All unused threaded openings shall be closed by suitably approved threaded plugs, recommended UL EBNV/7 approved.
7. All glands/reducers must be ingress protected to IP67 or better, to maintain the weatherproof rating of the equipment.

#### 3.3.2 Opening enclosure

To make the electrical connections it is recommended to remove the pump flange and slide out the terminal rail (fig 3)

This is done by removing the 5 x M6 cap head screws and carefully sliding out the pump flange, then sliding out the terminal rail to reveal the terminals.

Caution should be taken when removing the pump flange because internal wiring will remain connected to the terminal rail.

Extra care should be taken to ensure the enclosure flame paths are not damaged

Warning : Covers must not under any circumstances be removed until at least 5 minutes after the disconnection of power source.

EATON Installation & Maintenance Instructions IM-ADD-UL-XWW

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### 3.3.3 Electrical Installation Terminals

The pump unit is operated by the supply of a 24VAC switched supply which is connected to terminals 1 and 2 (fig 4).

Allowance is also made for the through connection of signal cables from the camera housing to aid in the installation of the system (fig 5).

Fig.4 Wiring connections

Fig.5 Conduit Connections Example

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## 4.0 Maintenance

Recommended inspection interval: 6 Months.

Inspect the unit every six months to ensure trouble free operation and extend product life.

Due to the rugged construction of the unit, little or no maintenance should be required.

However when the unit is exposed to extreme weather conditions the 'O' ring weather seals may need replacement approximately every five years.

Fixings and fastenings should be checked for tightness and integrity at regular intervals.

All cable entries and cables should be checked for integrity at regular intervals.

Extremely Harsh Environments may require more frequent inspection and maintenance checks.

At every Inspection carry out the following:

- Clean the unit.
- Check the 'O' ring weather seals and replace if necessary.
- Check and if necessary replace the internal pump hose section (see separate installation Note IMF-INTERNAL HOSE REPLACEMENT).
- Check and if necessary replace the washer nozzle.
- Check and if necessary replace the washer bottle.

Please read and be familiar with the instructions before servicing the Pan/Tilt or housing.

### 4.1 Corrosion Protection

Although all external metal components are produced from 316L Stainless Steel, if the units are not correctly maintained, handled and cleaned there is the possibility of mild discolouration due to Oxidation.

If ferrous metal equipment is used when handling the units, small ferrous deposits could be left on the stainless steel or if ferrous metal particles come to rest upon the units from

nearby works, this can cause accelerated corrosion of the ferrous deposits and discolour the units due to oxidation. In the event of ferrous deposits, the units should be cleaned immediately following EATON guidelines.

In atmospheres that are high in corrosive particles the units should be cleaned every 3 to 4 months using only water.

EATON takes no responsibility for oxidation due to failure in correctly following cleaning procedures.

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Stock No:

TM318 Issue B

## 5.0 Labelling

Certification Labels are made from stainless steel and affixed to the product using rivets.

The label shows:

- Name of Manufacturer
- Model/Type and Reference
- Operating Voltage
- Area Classification
- Serial Number, Year/Month/SN
- UL File Number

## 6.0 Specifications, Technical data & Special conditions for safe use.

Coding Class I Div 1 Group B,C,D

Class II Div 1 Groups E,F,G

T4A

IP67

-50°C to +70°C = Certified Ambient Temperature range

Construction: Stainless Steel AISI 316L

Poliethylene with anti-UV additive

Anti-static polyurethane tubing

Ingress Protection rating: IP 67 (XF26 housing only)

Supply voltage: 24VAC, 50/60Hz FHF signalling and alarmsCROUSE-HINDS

SERIES

Strobe light BLS

Optical signalling device for

indoor and outdoor applications

Overview

The BLS Strobe Light is an optical signalling device for universal use for example as continuous, warning or alarm strobe light. The ribbed cap is available in 5 different colours and achieves an extremely wide light dispersion.

The strobe light is available with a flash energy of 5 or 15 joule for continuous operation.

The plastic housing is made of impact-resistant

thermoplastic and the cap consists of impact-resistant plexiglass. The cable is led into the housing through a self-sealing grommet M16 x 1.5. The arrangement of the fastening bar allows for a surface or flush-mounted wiring.

#### Features

- Compensation valve to prevent condensation water
- Flash energy 5 Joule, 15 Joule
- Flash frequency 60/min.
- Continuous operation

#### Specifications

Housing Thermoplastic (ABS), impact-resistant

Colour Light grey

Cap Polycarbonat

Cap colour Transparent, red, amber, green, blue

Ingress protection IP 54 according to EN 60529

Protection class II

Cable gland 1x self-sealing grommet M16 x 1.5

Connection terminals Terminal capacity: 2,5 mm<sup>2</sup> single-wire

1,5 mm<sup>2</sup> fine-wire

Flash energy BLK 30/40: 5 joule

BLK 50/60: 15 joule

Flash frequency 60/min

Operating conditions Indoors or outdoors under protective roof

Operating position Any (preferably with cable glands facing downwards)

Operating mode Continuous operation acc. to IEC34, DIN EN 60034-1

VDE 0530 Niveau S1

Temperature range

Operation

Storage

-30 °C to +50 °C

-30 °C to +70 °C

Weight Approx. 0.7 kg

General arrangement drawing (All dimensions in mm)

Note: All specifications, dimensions, weights and tolerances are nominal (typical) and Eaton reserve the right to vary all data without prior notice. No liability is accepted for any consequence of use.

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July 2022

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Ordering data

\* The full article number is made up by appending the colour code to the article numbers given below.

Type Designation Input voltage Tolerance Current consumption Art. No.\*

BLS 30 Strobe light 24 VAC, 50-60 Hz 15-32 V 0.50 A FHF 224 151 ..

BLS 30 Strobe light 230 VAC, 50-60 Hz -10/+6 % 0.09 A FHF 224 152 ..

BLS 40 Strobe light 12 VDC 9-16 V 0.80 A FHF 224 153 ..

BLS 40 Strobe light 24 VDC 15-32 V 0.35 A FHF 224 154 ..

BLS 50 Strobe light 230 VAC, 50-60 Hz -10/+6 % 0.13 A FHF 224 162 ..

BLS 60 Strobe light 24 VDC 16-32 V 0.54 A FHF 224 164 ..

transparent 01

red 02

amber 03

green 04

blue 05

FHF Funke + Huster Fernsig GmbH

Gewerbeallee 15-19

D-45478 Mülheim an der Ruhr

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<http://www.eaton.com/signalling SIL>

2IEC 61508:2010

January 2020

SM5314 rev 1

Safety manual

MTL intrinsic safety solutions

DRAFT - 240120

MTL5314 Trip amplifier

4/20mA, for 2- or 3-wire transmitters

**\*FUNCTIONAL SAFETY MANAGEMENT**

This product is for use as an element within a Safety System conforming to the requirements of IEC 61508: 2010 and enables a Safety Integrity Level of up to SIL 2 to be achieved for the instrument loop in a simplex architecture.

\* Subject to specific operating conditions. Refer to content of this manual for details.

Eaton Electric Ltd, Luton is a certified Functional Safety Management company meeting the requirements of IEC61508: 2010 Part 1, Clause 6.

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DRAFT - 2401202

Trip Amplifier for 2- or 3-wire transmitters

This manual supports the application of the product in functional-safety related loops. It must be used

in conjunction with other supporting documents to achieve correct installation, commissioning and operation. Specifically, the product data sheet, instruction manual and applicable certificates for the product should be consulted, all of which are available on the MTL web site. In the interest of further technical developments, Eaton reserve the right to make design changes.

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#### Hardware Fault Tolerance (HFT) †

#### Module type 0, 1

#### MTL4541 SIL

#### 2IEC 61508:2010

† This module has an inherent fault tolerance of 0.

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SM5314 rev 1 rev 2

DRAFT - 2401203

### 1 INTRODUCTION

## 1.1 Application and function

The Trip Amplifier module type MTL5314 is intended for use with intrinsically safe 4-20mA process measuring

instruments located in a hazardous area of a process plant. It is also designed and assessed according to IEC

61508: 2010 for use in safety instrumented systems up to SIL 2.

The MTL5314 connects to a 2- or 3-wire 4-20mA intrinsically safe transmitter located in the hazardous area.

It can also receive a 4-20mA signal from an intrinsically safe current source, such as the output from a 4-wire

process instrument. The module provides one or two configurable alarm signals to the non-hazardous (safe) area

via changeover relays. Each relay may be configured individually to signal an alarm condition (relay de-energised)

when the input signal from the transmitter or current source is greater than or less than a pre-set value.

The trip-points are adjusted by the user via multiturn potentiometers accessible on the top of the unit. Switches

on top of the unit also set whether the trip-points are 'High trip' or 'Low trip'. The module is a member of the

MTL5000 range of products, and is intended for mounting within a secure equipment cabinet on 35mm DIN rail

complying with EN 50022. Electrical connections to the module are made via pluggable connectors on the top

and side of the module.

Figure 1.1 - Input and Output connections

## 1.2 Product build information covered by this manual

The information provided in this manual is valid for all product build revisions having a product build label as

shown below. This is found on the underside of the product.

Example: MTwwyyzzzzzz

ww = week

yy = year

z = 7 digit serial number

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## 2 SYSTEM CONSIDERATIONS

### 2.1 Permitted configurations

This manual describes two different configurations in which the MTL5314 may be used in functional safety

applications:

a) The MTL5314 is used in a "stand-alone" mode, in which the hazardous area terminals are connected to a 4-20mA transmitter or current source, and the non-hazardous relay terminals are

connected to a digital input card in a Logic Solver or to an alarm sounder or beacon that is part of the Safety Instrumented System. No other apparatus is connected into the 4-20mA current loop on the hazardous area side of the module.

b) The MTL5314 is used in conjunction with an Analogue Input module, which transfers the 4-20mA signal to the non-hazardous area for connection to receiving equipment that is not part of the

Functional Safety system. In this configuration, the hazardous area input terminals of the Analogue

Input module are connected in series with the 4-20mA loop current being passed by the transmitter, but power for the loop is provided by the MTL5314. The non-hazardous terminals of the

MTL5314 are connected to a digital input card in a Logic Solver or to an alarm sounder or beacon

that is part of the Safety Instrumented System.

These options are shown in Figure 2.0 (a) and Figure 2.0 (b), and are described in more detail in Section 3 of

this manual. The diagrams show the safety-rated and non-safety related system components, and are intended

to support an understanding of the application.

In both configurations, the MTL5314 module may be used in single-channel (1oo1) safety functions up

to SIL 2.

Figure 2.0 (a) - System Configuration: Stand-alone Trip function mode

(Logic Solver shown connected to Trip A)

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Figure 2.0 (b) - System Configuration: Trip function with 4-20mA current repeated to non-hazardous area

(Logic Solver shown connected to Trip A)

The shaded areas in each diagram indicates the safety-related system connection, while the power supply

connections are not safety-related. The term 'Logic Solver' has been used to denote the safety system

performing the monitoring function of Trip Amplifier output.

## 2.2 Associated System Components

There are many parallels between the loop components that must be assessed for intrinsic safety as well as for

functional safety. In both situations the contribution of each part is considered in relation to the whole.

In Functional Safety applications, the MTL5314 Trip Amplifier module provides an interface between a safety-

related process transmitter and a safety-related control system. The transmitter must be suitable for the process conditions and have been assessed and independently verified for use in a Safety Instrumented Function. The process transmitter shall have a normal operating range of 4-20mA but shall ideally be capable of working over an extended range of 3 to 22mA to allow for applications where the trip points are set outside the nominal range.

The Digital Input card in the Logic Solver shall have the ability to detect the status of the relays in the MTL5314 module. Although the MTL5314 module can be configured to provide two independent alarms, each of which can be set as a high or low trip point, the safety analysis presented in this manual assumes that only one trip output is used in the Safety Instrumented Function, meaning that the MTL5314 is set to trip either on a low input signal (Low Trip application) or on a high input signal (High Trip application).

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### 3 SELECTION OF PRODUCT AND IMPLICATIONS

#### 3.1 Stand-alone Trip function mode

In this mode of operation, the MTL5314 Trip Amplifier forms part of a high- or low-level Safety Instrumented Function (SIF), using the 4-20mA output from a field transmitter that is measuring a process variable such as pressure, temperature, flow or level. Refer to Figure 2.0 (a). The MTL5314 provides a single alarm trip to a Logic Solver, using the Trip A or Trip B relay connections. The 'Normally open' relay contacts must be used (ie terminals 11 & 12 for Trip A or terminals 8 & 9 for Trip B); this ensures that the SIF fails to a safe condition if the wiring between the Logic Solver and relay contacts is broken, or if power to the MTL5314 is lost.

In most applications, the trip point will be set within the nominal 4-20mA range. However, if the trip point is set outside this range but within the 0.5 to 22mA range of the MTL5314, care must be taken to ensure that the process transmitter is capable of reaching the trip value.

Use of the MTL5314 in two separate Safety Instrumented Functions (for example with Trip A set as a High

Alarm and Trip B set as a Low Alarm) is permissible only where special consideration has been given to

common-cause failures that may affect both SIFs. The second trip relay may however be

used to provide a non safety-related input to the basic process control system.

### 3.2 Trip function with 4-20mA current repeated to non-hazardous area

In this mode of operation, an MTL 4-20mA Analogue Input module is used in addition to the MTL5314, to

transfer the hazardous area loop current to receiving equipment in the non-hazardous area, as described in

Figure 2.0 (b). The MTL5314 trip function continues to act on the loop current, and to communicate the pre-

configured alarm conditions to the Logic Solver. The requirements stated below apply in addition to those in

3.1 above.

The MTL Analogue Input module is declared as “Non-interfering” in respect of the Safety Instrumented

Function that comprises the field instrument, MTL5314 Trip Amplifier and Logic Solver.

The MTL Analogue Input module must be one of the following types in the MTL4500 or MTL5500 ranges:

- MTLx541
- MTLx541S
- MTLx544
- MTLx544S
- MTLx541
- MTLx541S
- MTLx544
- MTLx544S

In order to ensure that the Alarm Trip Safety Instrumented Function continues to operate in the event that

the power supply to the MTL Analogue Input isolator fails, the user must ensure that the transmitter voltage

available from the MTL5314 (stated in the product data sheet as >17V @ 20mA) is at least 1.5V greater than

the total voltage developed across the transmitter and associated field wiring at 20mA.

The Analogue Input module must not itself be part of a Safety Instrumented Function. Its non-hazardous

4-20mA output signal may be part of the basic process control system, but must not be used as part of the

Safety Instrumented System. Note that HART communications are not supported on the 4-20mA signal.

Note:

- The MTL5314 is capable of operating in conjunction with MTL Analogue Input modules (such as MTL5541) that provide power for the hazardous area current loop, where the MTL5314 is connected in series with the process transmitter. This configuration also provides a means of

transferring the loop current to the non-hazardous area in addition to the trip alarms, and is shown

in other MTL documentation such as the MTL5314 product data sheet. However, this configuration is different to that described in 2.1 above, and has not been assessed for Functional

Safety applications.

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#### 4 ASSESSMENT OF FUNCTIONAL SAFETY

##### 4.1 Hardware Safety Integrity

The hardware safety integrity stated in this manual is drawn from a Failure Modes, Effects and Diagnostic

Analysis (FMEDA) for the MTL5314 Trip Amplifier, conducted on behalf of Eaton-MTL by Exida (Exida report

no. MTL 05/05-26 R007, version V1, revision R1). Minor amendments have been made in this manual where

appropriate, to ensure that the calculation of Safe Failure Fraction (SFF) is in compliance with IEC 61508-2: 2010.

The hardware assessment shows that MTL5314 module:

- has a hardware fault tolerance (HFT) of 0
- is classified as a Type A device (“non-complex” component with well-defined failure modes)
- has no internal diagnostic elements

The failure rates derived by the FMEDA for the MTL5314 are stated as FITs (failures per 10<sup>9</sup> hours, or failures

per thousand million hours) in the table below:

Model sd su dd du ne\* SFF

MTL5314, Low Trip 0 156 0 50 165 75.7%

MTL5314, High Trip 0 151 0 56 165 72.9%

The Safe Failure Fraction (SFF) shown in the table is calculated as  $(dd + sd + su) / (du + dd + sd + su)$ , and

stated as a percentage.

For both trip modes, the calculated SFF is between 60 and 90%, and therefore meets the requirements for SIL

2 according to Table 2 of IEC 61508-2: 2010, for a hardware fault tolerance of 0.

\* Note that “No-effect” failures ( ne ) are not used in the calculation of SFF. No-effect failures are

defined in IEC 61508-4: 2010 as failures of elements (or components) that are part of the safety function but have no effect on the safety function.

##### 4.2 Assumptions

The following assumptions have been made during this analysis:

- The fail safe state is defined as the alarm relay in the MTL5314 being de-energised.
- Only one trip output is used in the Safety Instrumented Function.
- A single failure will fail the entire product.

- Failure rates are constant; wear-out mechanisms are not considered.
- Propagation of failures is not relevant.
- All components that are not part of the safety function and cannot influence the safety function are excluded.
- The stress levels are typical for an industrial environment and can be compared to the Ground Fixed classification of MIL-HDBK-217F. This is similar to Class C (sheltered location) as defined in IEC 60654-1, with temperature and humidity levels within those stated in the product data sheet and Section 4.6 of this manual, and an average long-term temperature of 40°C.
- The module is powered from a nominal 24V dc supply.
- Power supply failure rates are not considered.

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#### 4.3 Systematic Safety Integrity

The MTL5314 module has a systematic safety integrity measure of SC 2. This has been established using compliance Route 1S, as described in IEC 61508-2: 2010, section 7.4.2.2 c.

#### 4.4 SIL Capability

Considering both the hardware safety integrity and the systematic capability, this allows the module to be used

in safety functions up to SIL 2 in a simplex architecture (HFT=0). The hardware safety integrity assessment has

been conducted according to compliance Route 1H, as described in IEC 61508-2: 2010, section 7.4.4.

Note:

- Independent of hardware architecture and systematic capability considerations, the hardware probability of failure for the entire safety function needs to be calculated for the application to ensure the required PFH (for a high or continuous demand safety function) or PFDavg (for a low demand safety function) for the SIL is met.

#### 4.5 EMC

The MTL5314 module is designed for operation in normal industrial electromagnetic environment but, to

support good practice, the module should be mounted without being subjected to undue conducted or radiated

interference. See Appendix A for applicable standards and levels.

#### 4.6 Environmental

The MTL5314 module is designed for operation over the temperature range from -20°C to +60°C, and at up to

95% non-condensing relative humidity.

The module is intended to be mounted in a normal industrial environment without

excessive vibration, as specified for the MTL5500 product range. See Appendix A for applicable standards and levels.

Continued reliable operation will be assured if the exposure to temperature and vibration are within the values given in the specification.

## 5 INSTALLATION

There are two aspects of safety that must be considered when installing the MTL5314 module. These are:

- Functional safety
- Intrinsic safety

To comply with intrinsic safety requirements, reference should be made to the relevant sections in the instruction manual INM5500, which is available to download from the Eaton-MTL website.

In many countries

there are also specific codes of practice and industry guidelines, which must also be adhered to.

Provided that these installation requirements are followed then there are no additional environmental factors to

meet the needs of applying the products for functional safety use.

To guard against the effects of dust and water the modules should be mounted in an enclosure providing at

least IP54 protection degree, or the mounting location should provide equivalent protection such as inside an equipment cabinet.

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## 6 MAINTENANCE

To follow the guidelines relating to operation and maintenance of intrinsically safe equipment in a hazardous

area, yearly periodic audits of the installation are required by the various codes of practice.

In addition, proof-

testing of the loop operation to conform with functional safety requirements should be carried out at the

intervals determined by safety case assessment.

Proof testing must be carried out according to the application requirements, but it is recommended that this be

performed at least once every three years.

Refer to Appendix B for the proof testing procedure for the MTL5314 module.

Note that there may also be specific requirements laid down in the E/E/PE operational maintenance

procedure for the complete installation.

If an MTL5314 module is found to be faulty during commissioning or during the normal lifetime of the product,

then such failures should be reported to the local Eaton-MTL office. Where appropriate, a Customer Incident Report (CIR) will be notified by Eaton to enable the unit to be returned to the factory for analysis. If the unit is within the warranty period and the failure is due to defective components or manufacture, then a replacement unit will be sent. Consideration should be given to the service lifetime for a device of this type, which is in the region of ten years. Operating an MTL5314 module for longer than this period could invalidate the functional safety analysis, meaning that the overall safety function no longer meets its target SIL. If high failure rates of the module are detected in service, indicating that they have entered the 'end of life phase' of their service life, then they should be replaced promptly.

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## 7 APPENDICES

### 7.1 Appendix A: Summary of applicable standards

This annex lists all standards referred to in the previous sections of this document:

IEC 61508: 2010 Functional safety of electrical/electronic/programmable electronic safety-related systems. Parts 1 and 2 as relevant

EN 61131-2: 2003 Programmable controllers – Part 2: Equipment requirement and tests (EMC requirements)

EN 61326-1: 2013 Electrical equipment for measurement, control and laboratory use – EMC requirements. (Criterion A)

IEC 61326-3-1: 2017 Electrical equipment for measurement, control and laboratory use – EMC requirements – Part 3-1: Immunity requirements for equipment performing or intended to perform safety related functions (functional safety) – General industrial applications. (Criterion FS)

NE21:2007 Electromagnetic Compatibility of Industrial Process and Laboratory Control Equipment. (Criterion A)

Lloyds Register Type Approval System: 2002,

Test Specification Number 1.

(specifically vibration: 1.0mm displacement @ 5 to 13.2Hz and 0.7G acceleration @13.2Hz to 100Hz per IEC60068-2-6, test Fc)

EN 60068-2-27 Environmental testing. Test Ea and guidance. Shock. (Criterion FS)

Note that other standards are referenced in Exida report no. MTL 05/05-26 R007, version V1, revision R1, which was used for the derivation of failure rates used in this manual.

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## 7.2 Appendix B : Proof Test Procedure, MTL5314 Module

Confirmation, through testing, that a safety function will operate as designed, is a necessary periodic

activity to ensure that the probability of failure upon demand (PFDavg) is maintained.

In some applications, the user may prefer to conduct a proof test on the overall safety instrumented

function without dismantling or disconnecting the individual instrumentation components, in order to

avoid disturbing the integrity of the installation.

However, where it is deemed desirable to perform proof testing on the MTL modules individually,

the following procedure may be used. Proof tests of the other components of the loop must then

be conducted in accordance with their manufacturers' instructions, to maintain the integrity of the

overall safety function. Alternative proof tests may be devised and applied, provided they give a

similar level of test coverage that is appropriate to the safety function.

Observe normal anti-static precautions when handling equipment during device testing.

Remove the

MTL5314 from the target system and observe the following test sequence:

1. Select a variable current source or sink, according to which is most representative of the actual field device in the Safety Instrumented Function. A current sink is representative of typical 2 or 3-wire field transmitters, whereas a current source is representative of the 4-20mA output from 4-wire transmitters. The current source or sink should have a traceable calibration history.

2. Set the current source or sink to 12.0mA, and connect it to the appropriate input terminals on the MTL5314 module as shown in Figure 7.2.

3. Adjust the trip potentiometers on the top of the MTL5314 module for Alarms A and B in turn, until the associated LEDs just extinguish.

4. Set the current source or sink to 11.5mA

5. Using the switches on top of the module, set both Alarms to 'Low Alarm'.

6. Confirm that the LEDs and alarm relays comply with the status shown in 'Low Alarm' column of the table below. A multi-meter set to a low ohms range can be used to check that the relays are open or closed.

7. Set both Alarms to 'High Alarm', and confirm that the LEDs and alarm relays comply with the status shown in the 'High Alarm' column of the table.

8. Set the current source or sink to 12.5mA and repeat steps 5 to 7.

Current

High Alarm Low Alarm

LEDs

Alarm A

LEDs

Alarm A

Terminals  
11 - 12  
Terminals  
10 - 11  
Terminals  
11 - 12  
Terminals  
10 - 11  
Alarm B Alarm B  
Terminals  
8 - 9  
Terminals  
7 - 8  
Terminals  
8 - 9  
Terminals  
7 - 8  
11.5mA on closed open off open closed  
12.5mA off open closed on closed open  
continued  
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Figure 7.2 - Connections for testing MTL5314 module  
Source  
or  
sink  
6  
5  
4  
3  
2  
1  
7  
8  
9  
10  
11  
12  
13  
14  
Trip B  
Trip A  
Vs  
Vs

20 to 35V dc

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SM5314 rev 1 rev 2

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DRAFT - 20 November 2014

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The given data is only intended as a product description and should not be regarded as a legal warranty of properties or guarantee. In the interest of further technical developments, we reserve the right to make design changes.

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DRAFT - 240120

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Application Note 11/2017 AP040017EN

PowerXL™

DE1 Variable Speed Starters

Motor Data – Motor Protection – V/f curves – Slip Compensation

Level 2

1 – Fundamental – No previous experience necessary

2 – Basic – Basic knowledge recommended

3 – Advanced – Reasonable knowledge required

4 – Expert – Good experience recommended

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Danger! - Dangerous electrical voltage!

- Disconnect the power supply of the device.
- Ensure that devices cannot be accidentally restarted.
- Verify isolation from the supply.
- Cover or enclose any adjacent live components.
- Follow the engineering instructions (AWA/IL) for the device concerned.
- Only suitably qualified personnel in accordance with EN 50110-1/-2 (VDE 0105 Part 100) may work on this device/system.

· Before installation and before touching the device ensure that you are free of electrostatic charge.

· The functional earth (FE, PES) must be connected to the protective earth (PE) or the potential equalization.

The

system installer is responsible for implementing this connection.

· Connecting cables and signal lines should be installed so that inductive or capacitive interference does not

impair the automatic control functions.

· Suitable safety hardware and software measures should be implemented for the I/O interface so that an

open circuit on the signal side does not result in undefined states.

· Deviations of the mains voltage from the rated value must not exceed the tolerance limits given in the

specification, otherwise this may cause malfunction and/or dangerous operation.

· Emergency stop devices complying with IEC/EN 60204-1 must be effective in all operating modes. Unlatch-

ing of the emergency-stop devices must not cause a restart.

· Devices that are designed for mounting in housings or control cabinets must only be operated and con-

trolled after they have been properly installed and with the housing closed.

- Wherever faults may cause injury or material damage, external measures must be implemented to ensure a safe operating state in the event of a fault or malfunction (e.g. by means of separate limit switches, mechanical interlocks etc.).
- Variable speed starters may have hot surfaces during and immediately after operation.
- Removal of the required covers, improper installation or incorrect operation of motor or variable speed starter may destroy the device and may lead to serious injury or damage.
- The applicable national safety regulations and accident prevention recommendations must be applied to all work carried on live variable speed starters.
- The electrical installation must be carried out in accordance with the relevant electrical regulations (e. g. with regard to cable cross sections, fuses, PE).
- Transport, installation, commissioning and maintenance work must be carried out only by qualified personnel (IEC 60364, HD 384 and national occupational safety regulations).
- Installations containing variable speed starters must be provided with additional monitoring and protective devices in accordance with the applicable safety regulations. Modifications to the variable speed starters using the operating software are permitted.
- All covers and doors must be kept closed during operation.
- To reduce the hazards for people or equipment, the user must include in the machine design measures that restrict the consequences of a malfunction or failure of the variable speed starter (increased motor speed or sudden standstill of motor). These measures include:
  - Other independent devices for monitoring safety related variables (speed, travel, end positions etc.).
  - Electrical or non-electrical system-wide measures (electrical or mechanical interlocks).
  - Never touch live parts or cable connections of the variable speed starter after it has been disconnected from the power supply. Due to the charge in the capacitors, these parts may still be alive after disconnection. Consider appropriate warning signs.

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AP040017EN DE1 Motor Data – Motor Protection – V/f Curves – Slip Compensation Page 5 General

Devices of the series PowerXL™ DE1 are Variable Speed Starters for the supply of standard asynchronous motors. By default they are configured, that motors of the respective power class can be supplied without changing the settings. Many standard cases can be covered. There are some applications, which require an adaptation by changing parameters. In this Application Note the following aspects are covered:

- Adaptation to the connected motor
- Slip compensation

- Motor protection
- Setting the V/f curve
- Energy optimization

#### Motor data

Condition for a proper operation is the right connection (star / delta) of the motor to the output terminals of the device. The rated voltage of the motor windings is decisive.

Device Output Voltage Motor Connection

DE1-12... 3 x 230 V 230 / 400 V Delta

DE1-34... 3 x 400 V 230 / 400 V

400 / 660 V

Star

Delta

DE1-34... 3 x 400 V 230 / 400 V Delta

Special case: 87 Hz-curve (see Example 4 below)

An adaptation to the connected motor can be done with the following parameters:

· P-07 Motor Nom Voltage

· P-08 Motor Nom Current

· P-09 Motor Nom Frequency

· P-10 Motor Nom Speed

The respective values can be taken from the name plate of the motor or from the data sheet of the

motor manufacturer. They are used for the setting of the motor protection and define the V/f curve.

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Motor Nom Voltage (P-07)

Motor rated voltage (name plate) taking the connection (star / delta) into account. This value defines

the max. output voltage of the Variable Speed Starter. Is the output frequency higher than the rated

frequency of the motor (P-09), the output voltage remains on the value set with P-07. See also chap-

ter “V/f curve” below.

Devices of the series DE1 have a voltage compensation. That means, that the output voltage is kept

constant, even with fluctuation of the mains voltage. In case P-07 = 0 , the voltage compensation is

disabled. In this case the maximum output voltage of the device is equal to the mains voltage at the

input terminals.

In exceptional cases, a different setting of P-07 is necessary. See chapter “87 Hz curve”

PNU Parameter Name Range Default

211.0 P-07 Motor Nom Voltage 0 / 50 V ... U<sub>e</sub> U<sub>e</sub>

U<sub>e</sub> = Rated voltage of the device, e.g. 230 V or 400 V, depending on device type

**Motor Nom Current (P-08)**  
 Rated current of the motor. By default, parameter P-08 „Motor Nom Current“ is set to the rated current I<sub>e</sub> of the Variable Speed Starter. P-08 is also used to set the thermal protection for the motor.  
 See also chapter “Motor Protection”. In case the rated current of the motor is different to the one of the Variable Speed Starter, P-08 has to be set accordingly to provide a thermal motor protection.  
 It must be pointed out, that this current value is set, which is assigned to the type of connection of the motor. In the example above it is 3,2 A at 230 V (Delta) respectively 1,9 A at 400 V (Star).

PNU	Parameter Name	Range	Default
210.0	P-08 Motor Nom Current	0.1 · I <sub>e</sub> ... I <sub>e</sub>	I <sub>e</sub>

I<sub>e</sub> = Rated current of the device

**Motor Nom Frequency (P-09)**  
 Rated frequency of the motor. By default this parameter is set to the mains frequency (50 Hz in Europe, 60 Hz in USA) and doesn't need to be changed in the majority of cases.  
 In case, motors with rated frequencies different from the mains frequency (e.g. 200 Hz for fast rotating motors) or if the 87 Hz curve is used, P-09 has to be set accordingly.

PNU	Parameter Name	Range	Default
216.0	P-09 Motor Nom Frequency	20 ... 300 Hz	50 Hz resp. 60 Hz

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**Motor Nom Speed (P-10) (Switching from Hz to rpm, Slip compensation)**  
 P-10 = 0: Setting / display of the output frequency in Hz  
 P-10 > 0: all speed related parameters (P-01, P-02, P-20...P-23) are set and displayed in rpm. Furthermore the slip compensation is activated, which ensures, that the motor speed is kept constant even with changing loads. In case the value of P-10 corresponds to a synchronous speed (e.g. 3000 rpm for a 2 pole motor at 50 Hz), the speed is set and displayed in rpm, but the slip compensation is not activated.

With slip compensation      Without slip compensation

The slip is the difference between a synchronous speed because of a rotating field and the actual speed of the motor. The name plate in the example on page 5 shows a rated speed of 1410

rpm. It is a 4 pole motor with a synchronous speed of 1500 rpm. Between no load and rated load there is a slip of 90 rpm. Running the motor with a Variable Speed Starter, one wants to prevent the speed variance by compensating the slip.

With slip compensation: at load increase j voltage and frequency are increased accordingly k. The speed n1 remains constant. At load decrease voltage and frequency are reduced.

Without slip compensation: with load j the speed drops from n1 to n2 k, when unloading the speed increases again.

PNU Parameter Name Range Default  
 217.0 P-10 Motor Nom Speed 0 / 200 ... 18000 rpm 0 rpm  
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Motor protection

The Variable Speed Starters of the series DE1 own an internal motor protection function, which trips the drive after a certain time in case of overload. The display shows the fault message “l.t-trP”. The overload is related to the rated current of the motor, set with P-08.

In case the output current of the device exceeds the value set with P-08 „Motor Nom Current“, this status is displayed on the keypad.

7-Segment LED display: dots a...f are flashing  
 OLED display: text „O-L“ is displayed

It has to be considered that, similar to a thermal overload relay, the current is used to estimate the temperature inside the motor. This kind of “indirect temperature measurement” is sufficient in many cases, but doesn’t reflect the real temperature conditions inside the motor. In case of Variable speed it has to be taken into account, that the cooling of the motor is done by an impeller, which is mounted on the motor’s shaft. Therefore the cooling is reduced at lower speeds. Experience shows that this is not critical between approx. 40 % and 100 % speed, but below 40 % it can lead to problems, if the application requires full torque also in this range (= full amount of losses). In pump and fan applications where the torque is square with the speed, this effect is uncritical.

In case of steady operation with nearly rated load below 40 % rated speed it is recommended to use

motors with temperature sensors (thermistors or thermo contacts), which provide information about the real motor temperature. Thermistors as well as temperature contacts can be directly connected to DE1 devices.

Example thermistor Example temperature contact

Parameter P-15 has to be set in a way, that the function „External Fault“ (EXTFLT) is assigned to terminal 3 (DI3). During proper operation, a High-Signal is applied to terminal 3. In case of fault the temperature contact must open respectively the resistance of the thermistor has to increase. DE1 trips at a resistance of  $> 3.6 \text{ k}\Omega$ , Reset can be performed at values  $< 1.6 \text{ k}\Omega$ .

ATTENTION: Variable Speed Starters of the series DE1 are designed according IEC / EN 61800-5-1, which requires double isolation between mains circuits and circuits with low voltage. Inside the drive power part and control part are separated accordingly. In case temperature sensors inside the motor are connected to DE1, the sensors have to be double isolated against the motor windings, not to weaken the overall insulation system!

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When several motors are connected in parallel at the output of the Variable Speed Starter, each motor has to have a separate (external) protective device.

SwitchRemanentStorage (P-33)

Variable Speed Starters calculate the thermal image of the motor based on the current. In case the function “SwitchRemanentStorage” (P-33) is ON, the calculated value is stored automatically on power down. The stored value is used on next power up. If this function is disabled, the motor thermal history is reset to zero.

Hint: The thermal memory is also active when the Variable Speed Starter is powered up, but no START command active. This takes into account a cooling of the motor during this phase.

PNU Parameter Name Range Default

682.0 P-33 SwitchRemanentStorage 0 = ON

1 = OFF

0 = ON

If variable Speed Starters DE1 are used under the scope of UL, the remanent storage has to be active

(P-33 = 0).

V/f curve

The V/f curve determines the magnetizing of the motor. In the simplest case the V/f curve is linear

(default). This means that we have rated voltage at rated frequency and e.g. half of the rated voltage

at half of the rated frequency. This is sufficient in many cases. But there are also situations where the

V/f curve has to be adopted according to the requirements of the application, mostly in those cases

where the max speed is above rated speed or where high torque is required, even in the lower speed

range.

The following parameters influence the V/f curve

- P-01 f-max
- P-06 EnergyOptimizer
- P-07 Motor Nom Voltage
- P-09 Motor Nom Frequency
- P-11 V-Boost

f-max (P-01)

Determines the maximum output frequency of the device. Normally this corresponds with the motor

rated frequency set with P-09. In case P-01 is higher than P-09, the voltage is kept constant in the

range above P-07.

PNU Parameter Name Range Default

20.1 P-01 f-max f-min ... 5 · P-09 50 Hz

resp. 60 Hz

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Energy Optimizer (P-06)

The function „Energy Optimizer“ enables an automatic adaptation of the output voltage to the load

conditions. Objective is, to reduce losses inside the Variable Speed Starter as well as in the motor by

reducing the output voltage.

PNU Parameter Name Range Default

626.1 P-06 EnergyOptimizer 0 = OFF

1 = ON

0 = OFF

Motor Nom Voltage (P-07)

This value defines the maximum output voltage of the Variable Speed Starter. In the frequency range

above P-09, the output voltage remains at the value set with P-07.

PNU Parameter Name Range Default

211.0 P-07 Motor Nom Voltage 0 / 50 V ... U<sub>e</sub> U<sub>e</sub>

U<sub>e</sub> = Rated voltage of the device, e.g. 230 V or 400 V, depending on device type

Motor Nom Frequency (P-09)

This value defines the frequency at which the maximum output voltage is reached (cut-off frequency).

PNU Parameter Name Range Default

216.0 P-09 Motor Nom Frequency 20 ... 300 Hz 50 Hz

resp. 60 Hz

V-Boost (P-11)

Voltage boost in the lower frequency range to compensate the internal voltage drop of the motor.

This causes a better torque behavior in the lower frequency range. Too high values can lead to an

increased temperature inside the motor.

PNU Parameter Name Range Default

27.0 P-11 V-Boost 0 ... 40 % U<sub>e</sub> 3.0 %\*

\* 3.5 % at DE1...-129D6...

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Examples

Example 1: Linear V/f curve

The output voltage increases linear with the frequency from 0 up to the value set with P-07, which is reached at the frequency set with P-09. In the frequency range above P-09 the voltage remains constant. In the majority of cases the maximum frequency (P-01) corresponds to the rated frequency of the motor (P-09).

Parameters:

- P-01 = max. required frequency
- P-06 = 0 (Energy Optimization OFF)
- P-07 = max. voltage (mostly mains voltage)
- P-09 = rated frequency of the connected motor
- P-11 = 0 %

Example 2: Linear V/f curve with voltage boost

Because of the internal voltage drop of the motor there is a poor torque behavior in the low frequency range when the V/f curve is just linear. The torque behavior can be improved by increasing the voltage in the lower range. This is done with the parameter V-Boost (P-11).

The voltage starts at the value set with P-11 and increases linearly until it reaches the linear curve, defined by P-07 and P-09, at half of P-09.

Parameters:

- P-01 = max. required frequency
- P-06 = 0 (Energy Optimization OFF)
- P-07 = max. voltage (mostly mains voltage)
- P-09 = rated frequency of the connected motor
- P-11 = x % (according to the torque requirements. Too high values have to be prevented because of the increased losses inside the motor.)

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Example 3: Energy Optimization (automatic modification of the V/f curve)

In the previous examples there was a fixed voltage assigned to each frequency. There are also appli-

cations with different torque demands, also at the same speed / frequency. With a fixed V/f curve

the max. torque has to be taken into account without the possibility to reduce losses.

In case the Energy Optimization is active (P-06 = 1) the Variable Speed Starter detects a part load

automatically and reduces the voltage accordingly. When the load increases again, voltage is also

increased. To prevent oscillations inside the system the voltage variation is not done suddenly, but

over time. Therefore this function is not suitable for application with cyclic load changes.

Parameters:

- P-01 = required max. frequency
- P-06 = 1 (Energy Optimization ON)
- P-07 = max. voltage (mostly mains voltage)
- P-09 = rated frequency of the connected motor
- P-11 = 0 %

Example 4: 87 Hz – Curve

In the majority of cases standard asynchronous motors are used up to their rated frequency. The maximum output frequency of the Variable Speed Starter is 50 Hz. The power of the motor can be increased by  $\sqrt{3}$ , by increasing the frequency from 50 Hz to 87 Hz ( $50 \text{ Hz} \cdot \sqrt{3}$ ), keeping the flux (magnetizing current) constant at the same time.

Conditions at a 400 V mains

- The motor is wound for 230 / 400 V (not 400 / 690 V)
- The windings are connected in delta.
- The Variable Speed Starter has a maximum output voltage of 400 V and a maximum frequency of 87 Hz. This results in 50 Hz at 230 V.
- The Variable Speed Starter is selected for a current which is the rated current of the motor at 230 V.

## Parameters

- P-07 = 400 V
- P-09 = 87 Hz (with 50 Hz on the name plate)

ATTENTION: When using a 50 Hz motor at 87 Hz, possible imbalances of the rotor can cause mechanical damages.

It is recommended to contact the motor manufacturer before using this motor at speeds above rated speed.

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Example for selection:

Motor data

- 230 / 400 V
- 3,2 / 1,9 A
- 0,75 kW
- 1410 min<sup>-1</sup>
- 50 Hz

Selection

- Device rated for 400 V, but for the current which is assigned to 230 V (here: 3,2 A) à DE1-343D6FN-N20N.
- The power of the motor results in  $0,75 \text{ kW} \cdot \sqrt{3} = 1,3 \text{ kW}$  (rated torque at  $\sqrt{3}$  times rated speed).
- The synchronous speed of the motor is  $1500 \text{ rpm} \cdot \sqrt{3} = 2598 \text{ rpm}$
- The expected speed at rated load is  $2598 \text{ rpm} - 90 \text{ rpm} = 2508 \text{ rpm}$

Remark: 90 rpm corresponds to the slip speed (1500 min<sup>-1</sup> – 1410 min<sup>-1</sup>)

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Application Note 11/2017 AP040029EN

PowerXL™

DE1 Variable Speed Starter

Starting, Stopping and Operation

Level 2

- 1 – Fundamental – No previous experience necessary
- 2 – Basic – Basic knowledge recommended
- 3 – Advanced – Reasonable knowledge required
- 4 – Expert – Good experience recommended

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##### Danger! - Dangerous electrical voltage!

- Disconnect the power supply of the device.
- Ensure that devices cannot be accidentally restarted.
- Verify isolation from the supply.
- Cover or enclose any adjacent live components.
- Follow the engineering instructions (AWA/IL) for the device concerned.
- Only suitably qualified personnel in accordance with EN 50110-1/-2 (VDE 0105 Part 100) may work on this device/system.
- Before installation and before touching the device ensure that you are free of electrostatic charge.
- The functional earth (FE, PES) must be connected to the protective earth (PE) or the potential equalization.

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system installer is responsible for implementing this connection.

- Connecting cables and signal lines should be installed so that inductive or capacitive interference does not impair the automatic control functions.
- Suitable safety hardware and software measures should be implemented for the I/O interface so that an open circuit on the signal side does not result in undefined states.
- Deviations of the mains voltage from the rated value must not exceed the tolerance limits

given in the specification, otherwise this may cause malfunction and/or dangerous operation.

- Emergency stop devices complying with IEC/EN 60204-1 must be effective in all operating modes. Unlatching of the emergency-stop devices must not cause a restart.
- Devices that are designed for mounting in housings or control cabinets must only be operated and controlled after they have been properly installed and with the housing closed.
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- Transport, installation, commissioning and maintenance work must be carried out only by qualified personnel (IEC 60364, HD 384 and national occupational safety regulations).
- Installations containing variable speed starters must be provided with additional monitoring and protective devices in accordance with the applicable safety regulations. Modifications to the variable speed starters using the operating software are permitted.
- All covers and doors must be kept closed during operation.
- To reduce the hazards for people or equipment, the user must include in the machine design measures that restrict the consequences of a malfunction or failure of the variable speed starter (increased motor speed or sudden standstill of motor). These measures include:
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  - Electrical or non-electrical system-wide measures (electrical or mechanical interlocks).
  - Never touch live parts or cable connections of the variable speed starter after it has been disconnected from the power supply. Due to the charge in the capacitors, these parts may still be

alive

after disconnection. Consider appropriate warning signs.

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notice.

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#### 1 General

Depending on the application, demands on speed controlled systems can be much different.

The

spectrum reaches from a soft start up to cyclic operation in some seconds, from a spin start,

where the motor is turning already at the time of starting up to dynamic braking, to mention only a few aspects.

At default, variable speed starters of the series PowerXLTM DE1 are configured to cover a plurality of applications. Additional adaptation can be achieved by changing parameter values.

This Application Note describes

- the different possibilities at starting and stopping
- the respective control commands
- the setting of the relevant parameters
- the behavior in case of a fault
- measures to prevent unintended trips

Some required parameters are inside Level 2 of the menu. This level has to be activated by prompt-

ing the "Password Level2" (P-38) into P-14 (Password). Password Level2 is 101 by default.

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## 2 Power-on

Switching on the device means applying a voltage to the terminals L and N in case of single phase

supply respectively L1, L2 and L3 in case of three phase supply. The voltage rating depends on the device type.

When applying the supply voltage, the d.c. link capacitor will be charged. Current limiting elements

are used to prevent an inrush peak of the current. After the charging, the elements are bypassed.

They are not effective during operation. It has to be noted that the current limiting elements are not

foreseen for a continuous duty. Therefore the number of starts per time is limited. Typical value: 1

charging per 30 s.

If the application requires a more frequent starting, the starting and stopping of the motor has to be

done by the signals at the control terminals. The supply voltage remains at the terminals continuous-

ly and is only removed when the machine is switched off.

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## 3 Starting

### 3.1 Selection of the terminal configuration

The assignment of the terminals can be configured with parameter P-15 "DI Config Select".

By de-

fault P-15 = 0. Terminal 4 can be used as digital input as well as analog input. The conversion is done

automatically, based on the setting of P-15.

HIGH signal " 8 ... 30 V DC

LOW signal " 0 ... 4 V DC

Reference is always 0 V. The control inputs are galvanically separated from the power section, but

not among each other.

3.1.1 DI Config Select (P-15)

3.1.2 1 sense of rotation, control with FWD (P-15 = 3, 4, 5, 7)

FWD

START in clockwise direction (FWD = forward). When applying a HIGH signal to terminal 1, the motor

accelerates with the ramp set with P-03 "t-acc". Removing the signal leads to a stop. The behavior at

stopping depends on the setting of P-05 "Stop mode". At standstill the variable speed starter is disa-

bled.

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3.1.3 2 senses of rotation, direction selected with DIR (P15 = 8, 9)

START

Starts the motor. Applying a HIGH signal to terminal 1 leads to an acceleration with the ramp set with

P-03 "t-acc". Removing the signal leads to a stop. The behavior at stopping depends on the setting of

P-05 "Stop mode". At standstill the variable speed starter is disabled.

DIR

Selection of the sense of rotation

LOW = clockwise (FWD)

HIGH = counterclockwise (REV)

ATTENTION: In case REV is selected and the wire breaks, the motor will reverse! Alternative: Select

terminal configuration with FWD/REV

3.1.4 2 senses of rotation, direction selected with FWD and REV (P-15 = 0, 1, 2, 6)

FWD

START in clockwise direction (FWD = forward). When applying a HIGH signal to terminal 1, the motor

accelerates with the ramp set with P-03 "t-acc". Removing the signal leads to a stop. The behavior at

stopping depends on the setting of P-05 "Stop mode". At standstill the variable speed starter is disa-

bled.

REV

START in counterclockwise direction (REV = reverse). When applying a HIGH signal to terminal 2, the motor accelerates with the ramp set with P-03 "t-acc". Removing the signal leads to a stop. The behavior at stopping depends on the setting of P-05 "Stop mode". At standstill the variable speed starter is disabled.

In case FWD and REV are applied to the respective terminals at the same time, the output of the variable speed starter is disabled. At removing of one signal (FWD or REV) it restarts.

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### 3.2 Selection of the Start Mode

#### 3.2.1 Start Mode (P-30)

"Start Mode" determines the behavior of the motor in terms of enabling (Commands START, FWD, REV) and configures the automatic restart after the occurrence of a fault.

#### Edge-r

After applying the supply voltage or after a RESET, the motor will not start when the enable signal is still present at the terminal. To restart, a rising edge of the signal START/FWD/REV is necessary.

#### Auto-0

After applying the supply voltage or after a RESET, the motor will automatically start when the enable signal is still present at the terminal.

#### Auto-1 ... Auto-9

After applying the supply voltage or after a RESET, the motor will automatically start when the enable signal is still present at the terminal. After a trip because of a fault the variable speed starter automatically starts up to 5 trials (Auto-0 = 0 trials ... Auto-9 = 9 trials) in 20 s intervals to restart. As long as the supply voltage is still applied, the content of the counter remains. The number of restart trials is counted and if the motor doesn't restart with the last trial, it trips and displays a fault message. RESET has to be done manually.

**ATTENTION!**

An automatic restart is only possible, when the control commands are given via the terminals (P-12 = 0 and P-12 = 11).

Take care, that an automatic restart doesn't lead to a dangerous situation!

PNU	Parameter	Name	Range	Default

## 620.0 P-30 Start-Modus

0: Edge-r

1: Auto-0

2: Auto-1

3: Auto-2

4: Auto-3

5: Auto-4

6: Auto-5

7: Auto-6

8: Auto-7

9: Auto-8

10: Auto-9

1

Auto-0

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### 3.3 Starting a rotating motor

In some applications it can happen, that the motor turns already before switching on. One example

are fans, which spin because of the chimney effect inside a wind tunnel. Another example are drive

systems with high inertia, which didn't come to a stop after the latest switching off and which now

have to be started again. A direct switching of a variable speed starter on a rotating motor without

additional measures can lead to an overcurrent trip. To prevent this it is possible to stop the motor

before restarting it.

This function is disabled by default, because it leads to a starting delay, which is not acceptable in

some other applications. It can be activated with parameter P-25 "DCBrake".

#### 3.3.1 DCBrake (P-25), t-DCBrake@Stop (P-26), DCBrake Voltage (P-27)

Parameter P-25 „DCBrake“ determines, in which situations a DC braking is performed. In case the braking is required before starting, P-25 has to be set to 2 or 3.

When applying FWD, REV or START a DC braking starts (see

also „5.2 DC braking to standstill“). The strength and the

duration depend on the settings of P-26 “t-

DCBrake@Stop” and P-27 “DCBrake Voltage” (in percent of

the motor rated voltage P-07). With P-25 = 3 it has to be

noted, that the braking time before a start is the same as

after a stop.

During a DC braking the LED „Fault code“ on the front of the variable speed starter lights yellow.

PNU Parameter Name Range Default

2221.0 P-25 DCBrake

0: OFF

1: ON at Stop

2: ON before Start

3: ON before Start and at  
Stop

0

2222.1 P-26 t-DCBrake@Stop 0.0...10 s 0.0 s

2220.0 P-27 DCBrake Voltage 0.0...100 % 0.0 %

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### 3.4 Starting with the keypad

When using an external keypad DX-KEY-LED, parameter „Start Mode“ (P-30) is not effective.

To start

the drive a HIGH signal at terminal 1 is necessary as well as a push of the START button on the keypad.

The drive starts with the ramp defined by P-03 „t-acc“. Pushing the STOP button or removing the

signal at terminal 1 leads to a stopping. The behavior depends on the setting of P-05 “Stop Mode”.

ATTENTION! In case P-12 = 2 (digital reference, 2 directions) the START button of the keypad is also

used to reverse the drive. It has to be noted that the drive will restart with the same sense of rotation,

which was present before the last stop.

#### 3.4.1 Digital Reference Reset Mode (P-24)

In case a digital reference is used, e.g. operation with a keypad, it can be determined, if the drive will

restart with the speed, which it had before the latest stopping or with the minimum speed, set with

P-02 (f-min).

PNU Parameter Name Range Default

620.3 P-24 Digital Reference Reset Mode

0: Start with f-min

1: Start with latest speed  
before stopping

2: Start with f-min (Auto-r)

3: Start with latest speed  
before stopping (Auto-r)

0

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### 3.5 Frequency of starts

In applications with cyclic operation, a frequent starting and stopping can be required. It has to be

noted, that there are measures inside a variable speed starter, which ensure a reliable operation on

one hand and which are limitations at the same time on the other hand.

Limitations for the frequency of starts:

- charging circuit for the d.c. link (see chapter „Power-on“)

- o permitted frequency of starts: one time every 30 s

- o remedy: apply supply voltage constantly and use commands at the terminals (FWD / REV / START)

- demagnetization time of the motor

- o In case it is selected, that the drive coasts to stop (P-05 „Stop Mode“ = 0), it has to be ensured that the motor is demagnetized before the next start. Because of this, the next start is only possible after approximately 1 s.

- o remedy: select the stop mode with ramp (P-05 = 1). In this case the deceleration ramp (P-04) must not be set to 0.0 s!

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## 4 Operation

### 4.1 The ramps

The variable speed starters of the series PowerXLTM DE1 have two independent ramps:

- an acceleration ramp „t-acc“ (P-03)

- a deceleration ramp „t-dec“ (P-04)

The set times refer to the time between standstill and the rated frequency of the motor (P-09 „Mo-

tor Nom Frequency“) or vice versa.

In most cases the rated frequency of the motor (P-09) is equal to the max frequency (P-01).

In case a

motor is operated above its rated speed, this has to be taken into account when setting the ramp

times.

Calculation of the parameter values (P-03, P-04):

$$P-03 = t_1 \cdot P-09$$
$$P-01 \cdot P-04 = t_2 \cdot P-09$$

P-01

#### 4.1.1 t-acc (P-03), t-dec (P-04)

PNU Parameter Name Range Default

111.0 P-03 t-acc 0.00 s – 300 s 5.0 s

114.0 P-04 t-dec 0.00 s – 300 s 5.0 s

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## 4.2 Skip frequencies to avoid resonances

In some applications an operation of the motor in a certain frequency band leads to

mechanical res-

onances, which can end up in a destruction of machine parts. The devices of the series PowerXLTM

DE1... have the possibility to skip this frequency band for steady operation to avoid this effect.

Fading out frequencies is possible with all kind of reference signals, not depending on where they come from, e.g. analog input, fixed frequency, digital reference ... , whatever is selected.

The band width is determined by P-42 "f-SkipBand1", while the center point is defined by P-43 "f-Skip1". The diagram on the left hand side shows the behavior. Setting P-26 to zero, deactivates the function.

REF = Reference

Example:

A motor runs up to 50 Hz. In the range between 15 Hz and 25 Hz mechanical resonances can occur.

Therefore the motor may not run inside this range steadily.

Band width:  $P-42 = 25 \text{ Hz} - 15 \text{ Hz} = 10 \text{ Hz}$

Center point:  $P-43 = 15 \text{ Hz} + 25 \text{ Hz}$

$2 = 20 \text{ Hz}$

How it works:

The reference is below the disabled range. " Drive runs with the set frequency. " Increase of refer-

ence into the disabled range " Motor accelerates and remains at the lower limit (in this example: 15

Hz). " Increase of reference above the disabled range " Motor accelerates with the ramp, set with

P-03 "t-acc" to the new speed. " Motor operates above the disabled range according to the refer-

ence. " Reduction of reference into the disabled area " Motor decelerates and remains at the up-

per limit (in this example: 25 Hz). " Reduction of reference below the disabled area " Motor decel-

erates with the ramp, set with P-04 "t-dec" to the new speed.

PNU Parameter Name Range Default

22.0 P-42 f-SkipBand1 0...P-01 0 Hz1)

21.0 P-43 f-Skip1 0...P-01 0Hz1)

1) The default setting of P-10 "Motor Nom Speed" = 0. In this case the values for P-42 and P-43 are

given in Hz. When P-10 is different from „0“, P-42 and P-43 have to be set in min-1.

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4.3 Preventing overvoltage trips

4.3.1 Overvoltage Control (P-31)

When the deceleration time is set too short, overvoltage trips of the variable speed starter can occur

because of energy feedback from high inertia loads into the DC link.

Variable speed starters DE1 have an internal algorithm to prevent overvoltage trips in regenerative

mode. Output voltage and frequency are adopted in a way that energy feedback is prevented.

Application examples:

- Ramp down time set too short: the overvoltage control extends the ramp automatically to avoid regeneration

- The motor is driven by the load, e.g. washing machines and other applications with imbalance. To prevent overvoltage trips the variable speed starter increases the output voltage and frequency automatically. The result is a small increase in speed which is acceptable in many applications.

The overvoltage control can be disabled with parameter P-31 "Overvoltage Control". In this case an

overvoltage trip can be prevented by increasing the ramp down time with P-04 "t-dec".

PNU Parameter Name Range Default

626.3 P-31 Overvoltage Control 0 = enabled

1 = disabled 0

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#### 4.4 Behavior in case of a fault

The variable speed starters of the series DE1 have multiple internal monitoring functions.

When a

deviation from proper operating conditions is detected, the variable speed starter is disabled and the

contact between the terminals 13 and 14 opens.

Hint: on the variant DE11 the function of the relay can be configured with P-51. In this case the con-

tact opens with P-51 = 0, 1, 3 or 8.

Fault indication by

- flashing of the LED "Fault Code" on the front of the device

- a message on the display in case the external keypad DX-KESY-LED is used.

Possible reasons and remedy can be found in chapter 4.3.3 "Fault messages – possible causes – rem-

edy".

##### 4.4.1 Last Fault (P-13)

The latest four fault messages are stored inside the fault register (P-13) in the sequence of their oc-

currence. The newest fault message is displayed first on the external keypad DX-KEY-LED.

Other fault

messages can be accessed by pressing the p button on the keypad multiple times. Flashing dots on

the seven segment display show the sequence.

Latest message = no dot

Last but one message = one flashing dot ....

The fault register will not be cleared in case the default settings are restored.

PNU Parameter Name Range Default

947.0 P-13 Last Fault see „Fault messages ....“ -

4.4.2 Reset after fault " Manual or automatic restart?

After the occurrence of a fault the reason has to be eliminated and after a RESET the drive can start

again. The parameter “Start Mode” (P-30) determines, if a RESET has to be done manually or an au-

automatic restart is possible. See 3.2 “Selection of the Start Mode”. Take care, that an automatic restart

doesn't lead to a dangerous situation!

Following measures lead to a manual reset:

- Pushing the STOP button on the external keypad DX-KEY-LED
- Disconnecting and reapplying the supply voltage
- Removing of the enable signal (FWD, REV, START) and reapplying

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Note:

The fault messages h-OI, O-I and I.t-trP occur, because of an overcurrent trip of the device. A delay time between the occurrence and a possible reset prevents damages of the device.

The

delay time is increased with each trial.

Reset Delay time

1st trial 2 s

2nd trial 4 s

3rd trial 8 s

4th trial 16 s

5th trial 32 s

each further trial 63 s

4.4.3 Fault messages – possible causes – remedy

The column „Message“ contains the code of the LED „Fault Code“ on the front of the variable speed

starter as well as the message on the display of the external keypad DX-KEY-LED.

Message Possible causes and remedy

LED "RUN"

flashes green

Stop

No actual fault. Drive is disabled.

LED „Status“

flashes red

U.Volt

Undervoltage in the d.c. link. Remark: This message generally appears when the supply voltage is disconnected from the drive and the d.c. link voltage is reduced. This is NO fault situation. When the message occurs during operation:

- Supply voltage too low " please check
- Check all components / devices, which are part of the supply circuit of the drive (protective devices, contactors, chokes...) for a proper connection and contact resistance.

„Fault Code“:

1 x flash,

2 s OFF

O-I

Instantaneous overcurrent on the variable speed starter output

- Fault occurs immediately on drive enable or run command:
- Check connection between drive and motor
- Check motor windings on short circuit or ground fault.
- Fault occurs during motor starting:
- Check the motor is free to rotate and there are no mechanical blockages
- Motor with mechanical brake: Check, if brake is released.
- Check for the correct star-delta wiring
- Check, if the motor nameplate current is correctly entered into P-08 (Motor Nom Current)
- Increase the ramp time in P-03 (t-acc)
- Reduce motor boost voltage setting in P-11.
- Fault occurs when motor operates at constant speed:
- Check, if motor is overloaded
- Fault occurs during motor acceleration or deceleration:
- The acceleration and deceleration ramp times are too short and require too much power. If P-03 / P-04 cannot be increased, a bigger drive may be required.

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Message Possible causes and remedy

„Fault Code“

2 x flash

2 s OFF

E-trip

External fault (at terminal 3).

- P-19 "DI3 Logic" = 0 (= Default): A HIGH signal must be applied to this input to operate the drive. In case a thermistor is connected: check motor temperature.
- P-19 "DI3 Logic" = 1: A LOW signal must be applied to this input to operate the drive.

„Fault Code“

3 x flash

2 s OFF

O.Volt

Overvoltage in the d.c. link

- Check if the supply voltage is inside the tolerance for the drive.
- Check if the overvoltage control is enabled (P-31 = 0)
- When the fault occurs while decelerating or stopping: increase ramp down time (P-04) or enable overvoltage control

„Fault Code“

4 x flash

2 s OFF

I.t-trP

Motor is overloaded. The thermal protection has tripped after delivering > 100 % of the current set in P-08 for a certain time.

- Check if the value of P-08 is equal to the motor rated current
- Check motor connection (star / delta)
- Flashing dots on the display indicate an operation with overload (> P-08). Increase ramp time or decrease load in this case.
- Check the load mechanically to ensure it is free and no jams, blockages or other mechanical faults exist.

„Fault Code“

5 x flash

2 s OFF

O-t

Heatsink overtemperature. The drive is too hot.

- Check the ambient temperature around the drive is within the specified range (maximum 50 °C / 60 °C, partly with derating)
- Ensure sufficient cooling air is free to circulate around the drive (distance to other devices above and below the variable speed starter).
- Improve cooling of the control cabinet, when necessary.
- The cooling slots may not be closed e.g. by pollution or by devices which are mounted too close

„Fault Code“

6 x flash

2 s OFF

Internal fault in power section " Please refer to your next Eaton sales office.

„Fault Code“

7 x flash

2 s OFF

SC-trp

Loss of the serial communication

- Check, if the connection to drives and other devices in the network is

correct

· Each participant in the network must have its own unique address. Two devices with the same address are not allowed.

„Fault Code“

8 x flash

2 s OFF

P-dEf

Default parameters have been loaded

„Fault Code“

9 x flash

2 s OFF

Distorsion of the d.c. voltage

„Fault Code“

10 x flash

2 s OFF

4-20 F

Analog input current out of range

· Check settings of P-16 for AI1

· In case of 4-20mA: Check reference signal on wire break

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Message Possible causes and remedy

„Fault Code“

11 x flash

2 s OFF

U-t

Undertemperature. This message is displayed, when the ambient temperature is below – 10 °C. To start the drive, the temperature must be above this value.

„Fault Code“

12 x flash

2 s OFF

Th-flt

Thermistor on the heatsink is faulty. Please refer to your next Eaton sales office.

„Fault Code“

13 x flash

2 s OFF

dAtA-F

Fault in the internal memory. Parameters are not saved and default settings are reloaded. Try to save the (again modified) parameters again. If the message still appears: Please refer to your next Eaton sales office.

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## 5 Stopping

There are multiple possibilities to stop a variable speed drive:

Possible with DE1? Accessories required

Switch off, drive coasts to standstill YES None

Ramp down to standstill YES None

Ramp down to standstill with overvoltage

control YES None

Dynamic braking with brake resistor No -

DC braking YES None

Feedback energy to the mains NO -

Mechanical brake (Variant DE11 only) YES None. Control with DE11

### 5.1 Ramping down or coasting?

Parameter P-05 „Stop Mode“ determines, if the motor coasts or if it ramps down when the enable

signal (FWD, REV, STOP) is removed.

#### 5.1.1 Stop Mode (P-05)

Coast to stop (P-05 = 0):

When the enable signal is removed, the output of the inverter is disabled and the motor coasts to stop.

Ramp to stop (P-05 = 1):

When the enable signal is removed, the motor ramps to standstill with the ramp set with P-04.

ATTENTION: In a drive system the energy always flows from the subsystem with the higher frequency

to the one with lower frequency. If the output frequency of the variable speed starter is reduced too

fast (deceleration ramp too short) and the motor still turns at a higher speed than the one corre-

sponding to the output frequency of the inverter because of its inertia, the motor becomes a genera-

tor and feeds back energy into the d.c. link. This leads to an increase of the d.c. link voltage and pos-

sibly to a trip with the message O.Volt (Overvoltage).

To prevent this, variable speed starters have the function “Overvoltage control”, which is enabled by

default. More details see chapter 4.2.1.

PNU Parameter Name Range Default

620.1 P-05 Stop Mode 0: coast to stop

1: ramp to stop 0

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## 5.2 DC braking to standstill

A DC current is injected into the motor, which generates a braking torque. The rotating energy of the machine is converted into heat, dissipated by the motor. This means that a DC braking must not be

performed quite often, not to overload the motor.

A DC braking cannot be used for a speed reduction e.g. from 1000 rpm to 800 rpm, but to a braking

to standstill only. The DC braking is also used to stop rotating motors (e.g. fans, which turn because

of the chimney effect inside a wind tunnel) before they start. This is to prevent overcurrent trips. See

chapter 3.3 "Starting a rotating motor".

5.2.1 DCBrake (P-25), t-DCBrake@Stop (P-26), DCBrake Voltage (P-27), f-DCBrake@Stop (P-28)

Parameter P-25 „DCBrake“ determines, in which situations a DC braking is performed. In case a DC

braking is required at stop, P-25 has to be set to 1 or 3.

The behavior at removal of the signals FWD / REV / START depends on the stop mode (P-05).

P-05 = 0 (coast to stop):

The DC braking starts, once the signal FWD / REV / START is removed.

P-05 = 1 (ramp to stop)

At removal of FWD / REV / START the motor decelerates with the ramp set with "t-dec" (P-04). Once

the frequency set with "f-DCBrake@Stop" (P-28) is reached, the DC braking starts.

The strength and the duration depend on the settings of P-26 "t-DCBrake@Stop" and P-27 "DCBrake

Voltage" (in percent of the motor rated voltage P-07). With P-25 = 3 it has to be noted, that the brak-

ing time before a start is the same as after a stop.

During a DC braking the LED „Fault code“ on the front of the variable speed starter lights yellow.

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PNU Parameter Name Range Default

2221.0 P-25 DCBrake

0: OFF

1: ON at Stop

2: ON before Start

3: ON before Start and at

Stop

0

2222.1 P-26 t-DCBrake@Stop 0.0...10 s 0.0 s

2220.0 P-27 DCBrake Voltage 0.0...100 % 0.0 %

2223.0 P-28 f-DCBrake@Stop 0 ... P-01 (f-max) 0.0 Hz

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5.3 Control of a mechanical brake

HINT: The information is exclusively valid for the variant DE11!

When a mechanical brake is used it should be activated at a certain speed. The relay contact be-

tween the terminals 13 and 14 have the possibility to generate a speed dependent signal.

The

threshold is adjustable. It can be configured, if the relay contact closes above or below the threshold.

Die Funktion des Ausgangs ist entsprechend zu konfigurieren.

Kind of signal Terminals Function Threshold

Normally open contact 13 / 14 P-51 „RO1 Function“ P-52 „RO1 Upper Limit“

5.3.1 RO1 Funktion (P-51), RO1 obere Grenze (P-52)

PNU Parameter Name Wertebereich Werk

451.0 P-51 RO1 Function 0: Drive running

1: Drive healthy

2: Motor at target speed

3: Drive tripped

4: Speed > RO1 Upper Limit (P-19)

5: Motor current > RO1 Upper Limit (P-19)

6: Speed < RO1 Upper Limit (P-19)

7: Motor current < RO1 Upper Limit (P-19)

8: Drive not enabled

9: Motor not at target speed

0

452.0 P-52 RO1 Upper Limit 0 % ... 200 % 1) 100 %

1) The percentage rate is related to the parameter selected with P-18 / P-25, in this case it is related to the max. frequency, set with P-

01. [www.eaton.eu](http://www.eaton.eu)

Application Note 11/2017 AP040042EN

PowerXL™

DE1 Variable Speed Starter

Set Point Setting

Level 2

1 – Fundamental – No previous experience necessary

2 – Basic – Basic knowledge recommended

3 – Advanced – Reasonable knowledge required

4 – Expert – Good experience recommended

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**Danger! - Dangerous electrical voltage!**

- Disconnect the power supply of the device.
- Ensure that devices cannot be accidentally restarted.
- Verify isolation from the supply.
- Cover or enclose any adjacent live components.
- Follow the engineering instructions (AWA/IL) for the device concerned.
- Only suitably qualified personnel in accordance with EN 50110-1/-2 (VDE 0105 Part 100) may work on this device/system.

· Before installation and before touching the device ensure that you are free of electrostatic charge.

· The functional earth (FE, PES) must be connected to the protective earth (PE) or the potential equalization.

The

system installer is responsible for implementing this connection.

· Connecting cables and signal lines should be installed so that inductive or capacitive interference does not impair the automatic control functions.

· Suitable safety hardware and software measures should be implemented for the I/O interface so that an

open circuit on the signal side does not result in undefined states.

· Deviations of the mains voltage from the rated value must not exceed the tolerance limits given in the

specification, otherwise this may cause malfunction and/or dangerous operation.

· Emergency stop devices complying with IEC/EN 60204-1 must be effective in all operating modes. Unlatch-

ing of the emergency-stop devices must not cause a restart.

· Devices that are designed for mounting in housings or control cabinets must only be operated and con-

trolled after they have been properly installed and with the housing closed.

· Wherever faults may cause injury or material damage, external measures must be implemented to ensure

a safe operating state in the event of a fault or malfunction (e.g. by means of separate limit switches, mechanical interlocks etc.).

· Variable speed starters may have hot surfaces during and immediately after operation.

· Removal of the required covers, improper installation or incorrect operation of motor or variable speed

starter may destroy the device and may lead to serious injury or damage.

· The applicable national safety regulations and accident prevention recommendations must be applied to

all work carried on live variable speed starters.

· The electrical installation must be carried out in accordance with the relevant electrical regulations (e. g.

with regard to cable cross sections, fuses, PE).

- Transport, installation, commissioning and maintenance work must be carried out only by qualified personnel (IEC 60364, HD 384 and national occupational safety regulations).

- Installations containing variable speed starters must be provided with additional monitoring and protective devices in accordance with the applicable safety regulations. Modifications to the variable speed starters using the operating software are permitted.

- All covers and doors must be kept closed during operation.

- To reduce the hazards for people or equipment, the user must include in the machine design measures

that restrict the consequences of a malfunction or failure of the variable speed starter (increased motor

speed or sudden standstill of motor). These measures include:

- Other independent devices for monitoring safety related variables (speed, travel, end positions etc.).

- Electrical or non-electrical system-wide measures (electrical or mechanical interlocks).

- Never touch live parts or cable connections of the variable speed starter after it has been disconnected from the power supply. Due to the charge in the capacitors, these parts may still be alive

after disconnection. Consider appropriate warning signs.

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descriptions contained herein. The information contained in this manual is subject to change without notice.

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### 1 General

Variable speed starters of the series PowerXLTM DE1 are used for the speed control of asynchronous

motors. The speed set point can be provided in different ways:

- via an analog signal at the control terminals
- as a fixed frequency value, which is selected by a digital command
- as a digital reference, which is adjusted via keypad or control terminals
- via a connected fieldbus.

These possibilities are the same for all DE1 power ratings.

This Application Note describes:

- the different ways of set point setting
- the handling of the references

Set point setting via fieldbus is not handled inside this Application Note.

Further information:

AP040036EN I/O Configuration describes:

- the existing input and output terminals
- the technical data
- the assignment of functions to terminals

AP040029EN Starting, Stopping and Operation describes:

- the different possibilities at starting and stopping
- the respective control commands
- the setting of the relevant parameters
- the behavior in case of a fault

Some required parameters are inside Level 2 of the menu. This level has to be activated by prompt-

ing the "Password Level2" (P-38) into P-14 (Password). Password Level2 is "101" by default.

Note: The keypad mentioned inside this application note is not part of the basic unit, but available as option DEX-KEY-LED. It is connected to the RJ45 jack on the front of the basic device with a patch cable.

### 1.1 Settings in Hz or rpm

Parameter P-10 „Motor Nom Speed“ determines, if the setting is done in Hz or rpm:

P-10 = 0: Setting / display of the output frequency in Hz

P-10 > 0: all speed related parameters (P-01, P-02, P-20 ... P-23) are set and displayed in rpm.

PNU Parameter Name Range Default

217.0 P-10 Motor Nom Speed 0 / 200 ... 30000 rpm 0 rpm

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### 1.2 Upper and lower speed limit

The speed range of the connected motor is determined by the parameters “f-min” (P-02) and “f-

max” (P-01). The reference is linear between these two values.

Please note, that the value of P-01 cannot be exceeded, respectively the value of P-02 cannot be

undercut. This is true for both senses of rotation.

Frequency respectively speed =  $P-02 + (\text{set point actual} / \text{set point max}) \cdot (P-01 - P-02)$

Example 1:

P-10 = 0 (setting / display in Hz)

P-01 = 50 Hz

P-02 = 0.0 Hz

Set point via analog input: 0 ... 10 V

Set point actually set: 5 V

Frequency =  $0 \text{ Hz} + (5 \text{ V} / 10 \text{ V}) \cdot (50 \text{ Hz} - 0 \text{ Hz}) = 0 \text{ Hz} + 0.5 \cdot 50 \text{ Hz} = 25 \text{ Hz}$

Example 2:

P-10 = 1470 rpm (setting / display in rpm)

P-01 = 1470 rpm

P-02 = 300 rpm

Set point via analog input: 0 ... 10 V

Set point actually set: 5 V

Speed =  $300 \text{ rpm} + (5 \text{ V} / 10 \text{ V}) \cdot (1470 \text{ rpm} - 300 \text{ rpm}) = 300 \text{ rpm} + 0.5 \cdot 1170 \text{ rpm} = 885 \text{ rpm}$

PNU Parameter Name Range Default

20.1 P-01 f-max P-02 ... 5 · P-09 (300 Hz max) 50.0 Hz

20.0 P-02 f-min 0.0 Hz ... P-01 0.0 Hz

Note:

- With values of P-10 > 0 the setting is done in rpm instead of Hz.

- The value, which can be set with P-01 „f-max“, is limited to five times „Motor Nom Frequen-

cy" (P-09) with a maximum of 300 Hz.

### 1.3 Behavior during change over between reference sources

During a change over between two reference sources, e.g. from an analog signal to a fixed frequency,

the new reference is approached with the actual ramp. The ramp times are determined by "t-acc" (P-

03) for acceleration and "t-dec" (P-04) for deceleration.

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### 1.4 Skip frequencies to avoid resonances

In some applications an operation of the motor in a certain frequency band leads to mechanical res-

onances, which can end up in a destruction of machine parts. The devices of the series PowerXLTM

DE1... have the possibility to skip this frequency band for steady operation to avoid this effect.

Fading out frequencies is possible with all kind of reference signals, not depending on where they come from, e.g. analog input, fixed frequency, digital reference ... , whatever is selected.

The band width is determined by P-42 "f-SkipBand1", while the center point is defined by P-43 "f-Skip1". The diagram on the left hand side shows the behavior. Setting P-26 to zero, deactivates the function.

REF = Reference

Example:

A motor runs up to 50 Hz. In the range between 15 Hz and 25 Hz mechanical resonances can occur.

Therefore the motor may not run inside this range steadily.

Band width: P-42 = 25 Hz – 15 Hz = 10 Hz

Center point: P-43 = 15 Hz + 25 Hz

2 = 20 Hz

How it works:

The reference is below the disabled range. " Drive runs with the set frequency. " Increase of refer-

ence into the disabled range " Motor accelerates and remains at the lower limit (in this example: 15

Hz). " Increase of reference above the disabled range " Motor accelerates with the ramp, set with

P-03 "t-acc" to the new speed. " Motor operates above the disabled range according to the refer-

ence. " Reduction of reference into the disabled area " Motor decelerates and remains at the up-

per limit (in this example: 25 Hz). " Reduction of reference below the disabled area " Motor decel-

erates with the ramp, set with P-04 "t-dec" to the new speed.

PNU Parameter Name Range Default

22.0 P-42 f-SkipBand1 0...P-01 0 Hz1)

21.0 P-43 f-Skip1 0...P-01 0Hz1)

1) The default setting of P-10 "Motor Nom Speed" = 0. In this case the values for P-42 and P-43 are

given in Hz. When P-10 is different from „0“, P-42 and P-43 have to be set in min-1.

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## 2 Analog reference

Variable speed starters of the series DE1 have one analog input:

- Analog input AI1 terminal 4

The configuration of the inputs and outputs is described inside the Application Note „I/O Configuration“ (AP040036EN). Beside the setting of the signal format (voltage or current), a scaling

factor can

be used to adopt the speed to the input signal.

### 2.1 Selecting the sense of rotation

The analog value at terminal 4 determines the amount of speed.

The control commands FWD and REV select clockwise or counter clockwise sense of rotation. If a

change of sense is required, the actual command (e.g. FWD) has to be removed first, before applying

the other one (e.g. REV). Applying FWD and REV simultaneously leads to a coasting of the motor.

### 2.2 Format of the analog value

The speed reference signal can be a voltage signal as well as a current one. It is invertible with Pa-

rameter P-18 in a way that a minimum signal leads to the maximum speed and vice versa.

Format P-18 counter clockwise rotation clockwise rotation

f-min f-max f-min f-max

0 ... 10 V (U 0-10) 0 0 V + REV 10 V + REV 0 V + FWD 10 V + FWD

1 10 V + REV 0 V + REV 10 V + FWD 0 V + FWD

0 ... 20 mA (A 0-20) 0 0 mA + REV 20 mA + REV 0 mA + FWD 20 mA + FWD

1 20 mA + REV 0 mA + REV 20 mA + FWD 0 mA + FWD

4 ... 20 mA (t 4-20) 0 4 mA + REV 20 mA + REV 4 mA + FWD 20 mA + FWD

1 20 mA + REV 4 mA + REV 20 mA + FWD 4 mA + FWD

4 ... 20 mA (r 4-20) 0 4 mA + REV 20 mA + REV 4 mA + FWD 20 mA + FWD

1 20 mA + REV 4 mA + REV 20 mA + FWD 4 mA + FWD

Note: In case a terminal configuration without the commands FWD and REV is selected with P-15, the

sense of rotation is set with the commands START and DIR.

- Clockwise rotation " START

- Counter clockwise rotation " START + DIR

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### 3 Fixed frequencies

Fixed frequencies are references, which are set once, e.g. during commissioning and which can be

selected by a digital command when required. The devices of the series DE1 have up to 4 fixed fre-

quencies f-Fix1 ... f-Fix4, which can be selected independently.

#### 3.1 Setting the frequency value

The setting of the fixed frequencies is done with P-20 up to P-23. Each value can be between zero

and the maximum frequency „f-max“ (P-01). It has to be noted, that the minimum frequency “f-min”

(P-02) will not be undercut, even when the fixed frequency is set to a lower value than P-02.

Example:

P-02 (f-min) = 10 Hz

P-20 (f-Fix1) = 5 Hz

When f-Fix1 is selected, the drive runs with 10 Hz!

PNU Parameter Name Range Default

5.1 P-20 f-Fix1 0 ... f-max (P-01) 20.0 Hz

5.2 P-21 f-Fix2 0 ... f-max (P-01) 30.0 Hz

5.3 P-22 f-Fix3 0 ... f-max (P-01) 40.0 Hz

5.4 P-23 f-Fix4 0 ... f-max (P-01) 50.0 Hz

#### 3.2 Selecting the sense of rotation

When using a fixed frequency the sense of rotation is determined by the commands FWD (clockwise)

and REV (counter clockwise) respectively DIR.

#### 3.3 Selecting the fixed frequency

The fixed frequencies can be activated via commands at the control terminals or via a field bus. The

selection is binary coded " for 4 fixed frequencies 2 Bits (FF20 and FF21) are required. The predefined

terminal configurations selected with P-15 enable access to the fixed frequencies.

##### 3.3.1 Selection with predefined terminal configurations (P-15)

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Inside the Application Note „I/O Configuration“ (AP040036EN) the configuration of the control ter-

minals is described. The following commands are important for the selection of fixed frequencies:

Abbreviation Function

FF1 Selection between the analog speed reference at analog input AI1 (terminal 6) and the fixed frequency 1 (f-Fix1), set with P-20.

Low = analog reference, High = f-Fix1.

FF20 / FF21 Selection of the digital frequencies f-Fix1 ... f-Fix4 with digital commands

FF20 FF21

f-Fix1 (P-20) L L

f-Fix2 (P-21) H L

f-Fix3 (P-22) L H

f-Fix4 (P-23) H H

### 3.3.2 Use of fixed frequencies in device functions

In certain situations, fixed frequencies are selected by a device function. Please take care, that there

is no collision because of user specific settings.

Fixed frequency Function

f-Fix1 When P-16 = 4 (analog inputs with a signal 4 ... 20 mA) the drive ramps to f-Fix1, in case of wire break in the reference circuit.

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## 4 Digital reference

The speed reference of the variable speed starters DE1 can also be given via digital commands. The

command UP (faster) increases the content of the reference counter, while DOWN (slower) reduces

it. The use of a digital reference has the advantage, that the reference can be set from different loca-

tions by paralleling push buttons, which is required in cases of large machines.

The setting occurs between the minimum speed / frequency (f-min, P-02) and the maximum fre-

quency / speed (f-max, P-01) with the actual ramp. The setting can be done with the keypad as well

as via terminals.

Example:

- When an enabled drive gets the "UP" command, the motor accelerates according to the ac-

tual ramp according to "t-acc" (P-03)

- When the „UP" command is removed, the speed remains constant. Applying "UP" again leads to a further acceleration. The maximum frequency / speed is defined with "f-max" (P-01).

- Consequently, applying „DOWN" leads to a speed reduction.

- When starting, the drive ramps to the speed determined by P-24 without an "UP" command.

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## 4.1 Configuration

### 4.1.1 Terminals / Keypad

With the settings P-15 = 4, 5 or 6 UP and DOWN commands via terminals are possible. In case a key-

pad DEX-KEY-LED is used, the reference value can be modified by using the arrow keys in addition.

With P-12 = 1 or 2 the variable speed starter can be started and stopped with the keys on the key-

pad. The behavior depends on the setting of P-24 "Digital Reference Reset Mode" (see 4.1.2)

#### 4.1.2 Reference at start and at changeover between speed sources

When starting a drive with a digital reference and when changing over from another speed source,

e.g. a fixed frequency, to a digital reference the reference value to be ramped to is determined by

the setting of P-24 "Digital Reference Reset Mode":

- P-24 = 0 or 2

- o Minimum speed

- o Example 1: Behavior at start

§ Drive runs with digital reference " switch OFF " restart " drive ramps to the minimum speed, set with P-02 „f-min“.

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- o Example 2: Behavior at changeover between speed sources

§ Drive runs with digital reference " Changeover to another speed source by applying a signal to the terminal " drive ramps to the speed required by the other speed source " Select "Digital reference" by removing the signal from the terminal " drive remains at the speed of the other speed source. The speed can now be changed with the keys on the keypad or with the signals UP and DOWN at the control terminals.

- P-24 = 1 or 3

- o Start with the latest speed before switching OFF or changing over to another speed source, set with the keypad or with the commands UP and DOWN at the terminals. This also applies to cases where another speed source was active at the time of switching OFF, but which is not selected at restart.

- o Example 1: The digital reference was set with the keypad to 1000 rpm. The speed source was changed from "Digital reference" to „Fixed Frequency 1" by means of a command at the control terminals. The drive is switched OFF when "Fixed Frequency1" is active.

§ Select „Digital reference" at the terminals " drive ramps to the 1000 rpm set with the keypad

§ „Fixed Frequency 1" was selected at the terminal when restarting " Drive ramps to Fixed Frequency 1

§ Changeover to "Digital reference" with the signal at the terminals " drive ramps to 1000 rpm

- o Example 2: Switching OFF when the drive runs with another speed source than the digital reference

§ Selection of the other speed source is still active at restart " drive ramps to

the speed of the other speed source.

§ Selection of the other speed source is not active at restart " drive ramps to the latest digital reference.

P-24 „Digital Reference Reset Mode“ also determines, how the drive can be started when P-12 = 1 or

2:

· P-24 = 0...1

o Starting of the drive by pushing the green START button on the keypad.

§ To start, an additional signal at the terminals is necessary (START / FWD / REV)

· P-24 = 2...3

o The start of the drive is carried out via the terminals (see also 4.1.1). A start with the button on the keypad is not possible.

o Note: With P-12 = 2 it is still possible to reverse the drive by pushing the green button on the keypad.

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PNU Parameter Name Range Default

620.3 P-24 Digital Reference Reset Mode 0 / 1: START via keypad

0: Minimum speed (P-02)

1: Previous speed from Keypad  
/ terminals (UP/DOWN)

2 / 3: START via terminals

2: Minimum speed (P-02)

3: Previous speed from Keypad  
/ terminals (UP/DOWN)

1

4.2 Bedienung

4.2.1 Starting / Stopping

Drives, which operate with a digital reference, can be started via terminals as well as via keypad. The

possibilities depend on the setting of the parameters P-12 “Local ProcessData Source”, P-15 “DI Con-

fig Select” and P-24 “Digital Reference Reset Mode”.

Note:

It can also be selected, that a signal from the terminal as well as one from the keypad must be ap-

plied to start the drive. In this case the signal at the terminal must be present before the button on

the keypad is pushed.

P-12 P-24 P-15 Starting via

terminal only

Starting via

keypad only

Starting via  
terminal AND  
keypad

P-12 = 0 P-24 = 0...3 P-15 = 4 / 5 / 6 YES NO NO

P-12 = 1 / 2 P-24 = 0 / 1 P-15 = 0 ... 9 NO NO YES

P-24 = 2 / 3 P-15 = 0 ... 9 YES\* NO NO

\*In this case the keypad cannot be used to start the drive, but with P1-12 = 2 the green button can still be used to reverse it (see 4.2.3)

#### 4.2.2 Increase / reduce speed

When using a digital reference the speed is changed via the commands UP and DOWN. For the duration of the commands the speed is increased respectively reduced. The commands are given via the keypad or via terminals.

The behavior of the drive is depending on keypad or terminal adjustment. While a command via terminals modifies the speed with the actual ramp directly, an adjustment with the keypad has a slope and works more smoothly. This results in a delay of about 1.5 s for every actuation. With the setting of P-12 = 1 or 2 a speed adjustment via keypad is always possible, an adjustment via terminals only with the settings P-12 = 1 or 2 AND P-15 = 4 / 5 / 6.

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Note:

- Simultaneous use of UP and DOWN (both via terminals or both via keypad) reduces the speed.
- The terminal command dominates the one from the keypad. This also means: DOWN via keypad and UP via terminal " the speed increases.
- A speed adjustment via keypad is also possible in cases where starting and stopping via keypad is disabled.

#### 4.2.3 Change sense of rotation

The sense of rotation at start with a digital reference is basically determined by the terminal commands. With P12 = 2 one has the possibility to reverse the motor by pressing the green Start button on the keypad. Behavior at start: see column "Sense of rotation at START" in the table below.

P-12 P-24 P-15

Sense  
of rotation  
via terminal

Sense  
 of rotation  
 via keypad  
 Sense of rotation at  
 START  
 P-12 = 0 P-24 = 0 ... 3  
 P-15 = 4 / 5 NO  
 NO  
 No change of sense of  
 rotation possible  
 P-15 = 6 YES Sense of rotation as  
 selected via terminals  
 P-12 = 1  
 P-24 = 0 ... 3  
 P-15 = 3 / 4 /  
 5 / 7 NO  
 NO  
 No change of sense of  
 rotation possible  
 P-15 = 8 / 9 YES  
 (DIR) Sense of rotation as  
 selected via terminals  
 P-24 = 2 / 3 P-15 = 0 / 1 /  
 2 / 6  
 YES  
 (FWD / REV)  
 P-12 = 2  
 P-24 = 0 ... 3  
 P-15 = 3 / 4 /  
 5 / 7 NO  
 YES  
 (INV)  
 Sense of rotation as  
 selected via termi-  
 nals, taking into ac-  
 count a possible in-  
 version at the time of  
 stopping the drive  
 (Start button on the  
 keypad).  
 P-15 = 8 / 9 YES  
 (DIR)  
 P-24 = 2 / 3 P-15 = 0 / 1 /  
 2 / 6

YES

(FWD / REV)

Note:

· P-15 = 0 / 1 / 2 / 6:

o Applying the FWD and REV commands simultaneously leads to a coasting of the motor

o In applications with reversion, the Stop Mode should be set in a way, that the ramp is active (P1-5 = 1). If this is not the case a changeover between the commands FWD and REV is detected as stop command and the drive behaves according the setting with P-05. After this, it restarts into the opposite direction. Starting a motor, which is still turning can lead to an overcurrent trip.

· P-12 = 2

o A possible inversion with the Start button on the keypad is stored at stop. The drive restarts with the same sense of rotation he had before stopping. Please note, that in this case the sense of rotation at restart cannot be clearly defined by the terminal commands.. [www.eaton.eu](http://www.eaton.eu)

Application Note 11/2017 AP040036EN

PowerXL™

DE1 Variable Speed Starter

I/O Configuration

Level 2

1 – Fundamental – No previous experience necessary

2 – Basic – Basic knowledge recommended

3 – Advanced – Reasonable knowledge required

4 – Expert – Good experience recommended

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Danger! - Dangerous electrical voltage!

- Disconnect the power supply of the device.
- Ensure that devices cannot be accidentally restarted.
- Verify isolation from the supply.
- Cover or enclose any adjacent live components.
- Follow the engineering instructions (AWA/IL) for the device concerned.
- Only suitably qualified personnel in accordance with EN 50110-1/-2 (VDE 0105 Part 100)

may work on this

device/system.

- Before installation and before touching the device ensure that you are free of electrostatic charge.

- The functional earth (FE, PES) must be connected to the protective earth (PE) or the potential equalization.

The

system installer is responsible for implementing this connection.

- Connecting cables and signal lines should be installed so that inductive or capacitive interference does not

impair the automatic control functions.

- Suitable safety hardware and software measures should be implemented for the I/O interface so that an

open circuit on the signal side does not result in undefined states.

- Deviations of the mains voltage from the rated value must not exceed the tolerance limits given in the

specification, otherwise this may cause malfunction and/or dangerous operation.

- Emergency stop devices complying with IEC/EN 60204-1 must be effective in all operating modes. Unlatch-

ing of the emergency-stop devices must not cause a restart.

- Devices that are designed for mounting in housings or control cabinets must only be operated and controlled after they have been properly installed and with the housing closed.

trolled after they have been properly installed and with the housing closed.

- Wherever faults may cause injury or material damage, external measures must be implemented to ensure

a safe operating state in the event of a fault or malfunction (e.g. by means of separate limit switches, mechanical interlocks etc.).

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- Variable speed starters may have hot surfaces during and immediately after operation.

- Removal of the required covers, improper installation or incorrect operation of motor or variable speed

starter may destroy the device and may lead to serious injury or damage.

- The applicable national safety regulations and accident prevention recommendations

must be applied to

all work carried on live variable speed starters.

- The electrical installation must be carried out in accordance with the relevant electrical regulations (e . g.

with regard to cable cross sections, fuses, PE).

- Transport, installation, commissioning and maintenance work must be carried out only by qualified per -

sonnel (IEC 60364, HD 384 and national occupational safety regulations).

- Installations containing variable speed starters must be provided with additional monitoring and protective

devices in accordance with the applicable safety regulations. Modifications to the variable speed star te rs

using the operating software are permitted.

- All covers and doors must be kept closed during operation.

- To reduce the hazards for people or equipment, the user must include in the machine design me asure s

that restrict the consequences of a malfunction or failure of the variable speed starter (increased motor

speed or sudden standstill of motor). These measures include:

- Other independent devices for monitoring safety related variables (speed, travel, e nd positions etc.).

- Electrical or non-electrical system-wide measures (electrical or mechanical interlocks).

- Never touch live parts or cable connections of the variable speed starter after it has been disc on-

nected from the power supply. Due to the charge in the capacitors, these parts may still be alive

after disconnection. Consider appropriate warning signs.

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## 1 General

The variable speed starters of the series PowerXLTM DE1 are configured for many applications by default. In addition there is the possibility to adopt the devices to the application. Not only internal variables like ramp times or speed are changed, but also different functions can be assigned to the terminals. This possibility is universal inside the DE1 series and does not depend on the power rating.

This Application Note describes

- the existing input and output terminals
- the technical data
- the assignment of functions to terminals
- the configuration of the I/Os

Wiring diagram of a variable speed starter DE1 with default settings

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## 2 Hardware

All signals at the input terminal have the same signal common (0 V). Terminal 4 can be used as digital input as well as analog input. The respective function depends on the configuration (see chapter 3ff).

### 2.1 Designation of the control terminals and technical data

Designation Function Default

0 V Signal common for all inputs (terminals. 1 ... 4) -

+ 10 V Control voltage and reference voltage

20 mA max.

Signal common: 0 V -

1 (DI1) Digital input 1 HIGH: 9 ... 30 V

10 V: 1,15 mA / 24 V: 3 mA FWD

2 (DI2) Digital input 2 HIGH: 9 ... 30 V

10 V: 1,15 mA / 24 V: 3 mA REV

3 (DI3) Digital input 3 HIGH: 9 ... 30 V

10 V: 0,12 mA / 24 V: 0,3 mA FF1

4 (AI1 / DI4) Analog input 1 or digital input 4

analog:

0 ... 10 V; 0,12 mA

0/4 ... 20 mA, RB = 500  $\Omega$

digital:

HIGH: 9 ... 30 V

10 V: 0,12 mA / 24 V: 0,3 mA

REF

(analog, 0 ... 10 V)

13 Relay RO1 (NO) 250 V, 6 A AC /

30 V, 5 A DC

RUN, device

enabled14

## 2.2 Wiring examples

The control terminals of the devices DE1 are fixed. On the variant DE11, the terminal block for the

control signals is pluggable. To apply control signals to the terminals, the internal 10 V as well as ex-

ternal voltages, e.g. 24 V from a PLC, can be used.

### 2.2.1 Example 1: Application motor starter

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### 2.2.2 Example 2: Application with variable speed

### 2.2.3 Example 3: Control voltage from an external voltage source

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### 2.2.4 Example 4: external reference value

### 2.2.5 Example 5: control by a PLC

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## 2.3 Relay output

Depending on the kind of load, we recommend the use of protection circuitry for the relay outputs.

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## 3 Configuration

The table gives an overview, how to determine the function of the single I/Os.

Designation

Selection / setting of

Function Format

(signal range)

Scaling

(Gain) Inversion Hysteresis Offset

0 V fixed - - - - -

+10 V fixed - - - - -

1 (DI1)

P-12 / P-15

- - - - -

2 (DI2) - - - - -

3 (DI3) - - P-19 - -

4 (AI1 / DI4) P-16 P-17 P-18 - P-44

DE1: 13 fixed - - - - -

DE1: 14 -

DE11: 13 P-51 - - - P-52 / P-53

/ P-54 -

DE11: 14

### 3.1 Inputs

The function of the inputs can be configured in different ways:

- using the default settings.
- configuration with the configuration module DXE-EXT-SET. The numbers at the selector switch correspond to the settings of P-15 in terminal mode (P-12 = 0)
- via the optional keypad DX-KEY-LED
- via the parameter software DrivesConnect

The available terminal combinations depend on the selection of the “Local ProcessData Source” (P-

12). Default: P-15 = 0, P-12 = 0.

#### 3.1.1 Terminal configuration

PNU Parameter Name Range Default

423.0 P-15 DI Config Select 0 ... 9 0

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For the terminal functions the following abbreviations are used:

Abbreviation Function

DIR Used for the selection of the sense of rotation in connection with the START command.

Low = cw (FWD )

High = ccw (REV)

ATTENTION: in case of a wire break the drive reverses in case REV is selected! Alternative: use configuration with FWD/REV.

DOWN “Reduce speed” command, when a digital reference is selected. Used in combination with the command UP. In case UP and DOWN are ap-

plied simultaneously. The motor reduces its speed for the duration of the simultaneous signals with the deceleration ramp set with “t-dec” (P-04).

ENA Enable variable frequency drive. To start the drive an additional start signal (START, FWD, REV) is necessary. When removing ENA, the motor coasts to stop.

ENAINV In case ENAINV is used instead of ENA, the sense of rotation is inverted, compared to the one determined by a keypad or a fieldbus.

Example: ENA + FWD = FWD, ENAINV + FWD = REV

ENAREF Enable signal for the speed reference. This signal is necessary to operate the variable speed starter in addition to START respectively FWD/REV. At disconnection of ENAREF the variable speed starter ramps to stand still, but the variable speed starter will not be disabled.

EXTFLT External fault. Enables the inclusion of an external signal into the fault messages of the variable speed starter.

P-19 = 0: During operation a High signal must be applied to the terminal. A Low signal leads to a trip with the message “E-trip”.

P-19 = 1: During operation a Low signal must be applied to the terminal. A High signal leads to a trip with the message “E-trip”.

FF1 Selection between the analog speed reference at analog input AI1 (terminal 4) and the fixed frequency 1 (f-Fix1), set with P-20.

Low = analog reference, High = f-Fix1

FF20 / FF21 Selection of the fixed frequency with digital commands. The fixed frequencies f-Fix1 ... f-Fix4 are defined with P-20 ... P-23.

FF20 FF21

f-Fix1 (P-20) L L

f-Fix2 (P-21) H L

f-Fix3 (P-22) L H

f-Fix4 (P-23) H H

FWD START with a clockwise rotating field (FWD = Forward). When applying a High signal to the respective terminal, the motor accelerates with the predefined ramp. Removing the signal leads to a stop. The stop behavior depends on the setting of P-05 “Stop Mode”. At standstill the variable speed starter is disabled. In applications with two directions, counter clockwise rotation is selected with REV. FWD and REV are logically connected (XOR). Applying both signals at the same time leads to a trip of the variable speed starter.

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Abbreviation Function

REF Analog input AI1 (terminal 4) is used as speed reference input.

P-16: Format (voltage input / current input ...)

P-17: Scaling

#### P-18: Inversion

REV START with a counter clockwise rotating field (REV = Reverse). When applying a High signal to the respective terminal, the motor accelerates with the predefined ramp. Removing the signal leads to a stop. The stop behavior depends on the setting of P-05 "Stop Mode". At standstill the variable speed starter is disabled. In applications with two directions, clockwise rotation is selected with FWD. FWD and REV are logically connected (XOR). Applying both signals at the same time leads to a trip of the variable speed starter.

START Starts and stops the motor. When applying a High signal to the respective terminal, the motor accelerates with the predefined ramp. Removing the signal leads to a stop. The stop behavior depends on the setting of P-05 "Stop Mode". At standstill the variable speed starter is disabled. In applications with two directions, the sense of rotation is selected with DIR or INV. In applications with Smartwire DT this signal is necessary in addition to the start command coming via bus. UP "Increase speed" command, when a digital reference is selected. Used in combination with the command DOWN. In case UP and DOWN are applied simultaneously. The motor reduces its speed for the duration of the simultaneous signals with the deceleration ramp set with "t-dec" (P-04).

#### 3.1.2 Displaying input signals

The status of the inputs can be displayed by selecting the respective parameters.

PNU Parameter Name Range Default

560.0 P00-01 Analog input1 0.0 ... 100 % input signal - 550.0

...

550.3

P00-04 DI1 Status 0 / 1 -

The value, displayed with P00-01, takes also a potential scaling factor (P-17) into account.

Example:

$P00-01 = \text{Signal at AI1 [\%]} \cdot P-17$

The display on the keypad can be used to see the status of the digital inputs DI1 ... DI4. It starts with

DI1 on the left hand side of the display. 0 = Low signal, 1 = High signal at the respective input terminal.

Voltages between 9 and 30 V are identified as High signal. If an input is configured as analog input, its

status is displayed in P00-04 with 0 with voltage levels up to 9 V, above this with 1.

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#### 3.1.3 Configuration of digital input DI3

Digital input 3 (Terminal 3) can be used to include an external signal into the fault messages.

Parameter P-19 (DI3 Logic) determines, if a HIGH or a LOW signal is necessary at terminal 3 to indicate a proper status.

PNU Parameter Name Range Default

650.2 P-19 DI3 Logic 0 " HIGH = OK, LOW = fault  
1 " LOW = OK, HIGH = fault 0

DI3 can be configured in a way, that a thermistor can be used to protect the connected motor. In this case P-19 must be set to 0.

Parameter P-15 has to be set in a way, that the function „External Fault“ (EXTFLT) is assigned to terminal 3 (DI3). During proper operation, a High-Signal is applied to terminal 3. In case of fault the temperature contact must open respectively the resistance of the thermistor has to increase. DE1 trips at a resistance of > 3.6 kΩ, Reset can be performed at values < 1.6 kΩ.

ATTENTION: Variable Speed Starters of the series DE1 are designed according IEC / EN 61800-5-1, which requires double isolation between mains circuits and circuits with low voltage. Inside the drive power part and control part are separated accordingly. In case temperature sensors inside the motor are connected to DE1, the sensors have to be double isolated against the motor windings, not to weaken the overall insulation system!

In applications with fire mode (P-45 = 1...4) digital input DI3 is used to apply the fire mode signal to the variable speed starter. Parameter P-19 (DI3 Logic) is not effective in this case. Further information about fire mode is available in application note AP040181EN “DE1 Fire Mode”.

### 3.1.4 Configuration of analog input AI1

At analog input AI1 (terminal 4) it is also possible to take a scaling factor into account.

- Signal range: Selection of the kind of signal at the analog input. The maximum value of the signal corresponds to the maximum speed / frequency set with P-01.
- Gain: With the gain the analog input can be scaled.
- AI1 Invert:

P-18 = 0 " 0 V = minimum frequency, 10 V = maximum frequency  
P-18 = 1 " 0 V = maximum frequency, 10 V = minimum frequency

- Offset AI1:

With P-44 an offset to the signal at analog input AI1 can be set. It is adjustable in the range between -1.000 and + 1.000. It must be noted, that a negative offset value will be added to the one at AI1, a positive one will be subtracted. Example: P-44 = -0.2 " 20 % of the full scale value are added to the signal coming from AI1. The gain, set with P-17, is also effective for the offset signal.

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PNU Parameter Name Range Default

260.0 P-16 AI1 Signal Range

0: 0 ... 10 V (U 0–10)

1 : 0 ... 20 mA (A 0–20)

2: t 4 ... 20 mA (trip in case of wire break) (t 4–20)

3: r 4 ... 20 mA (ramps to f-Fix1 (P-20) in case of wire break) (r 4–20)

0

261.0 P-17 AI1 Gain 0.100 ... 2.500 1.000

267.0 P-18 AI1 Invert 0 = no inversion

1 = inversion 0

262.0 P-44 AI1 Offset -1.000 ... +1.000 0

### 3.2 Relay output

The function of the output relay between the terminals 13 and 14 of the devices DE1 is fixed (RUN).

The contact closes when

- the device is supplied
- no fault message is present
- the start signal is applied (FWD/REV/START)

The contact opens

- at disconnection of the supply voltage
- in case of a fault
- when removing the start signal where the point of opening depends on the selected „Stop Mode“:

o P-05 = 0 " coasting. The contact opens as soon as the start signal is removed.

o P-05 = 1 " ramping. The contact opens when the motor is at stand still after a deceleration with the ramp set with „t-dec“ (P-04).

On variants DE11 the function of the relay contact can be configured.

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### 3.2.1 Selecting the function of RO1 (DE11 only)

The function of relay RO1 (terminals 13 and 14) can be selected with parameter P-51.

For the settings P-51 = 4 ... 7, switch on threshold level (P-52) and a hysteresis of the relay (P-53) can be defined.

Switch OFF threshold = „RO1 Upper Limit“ (P-52) – „RO1 Hysteresis“ (P-53)

P-51 = 4 or 5: output will be logic 1 if the value > „RO1 Upper Limit“ , output will be logic 0 if value < Switch OFF threshold

P-18 = 6 or 7: output will be logic 0 if the value > „RO1 Upper Limit“ , output will be logic 1 if value < Switch OFF threshold

P-55 defines a switch-on delay, before the relay switches from logic 0 to logic 1.

PNU Parameter Name Range Default

451.0 P-51 RO1 Function 0: RUN, enable (FWD/REV)

1: READY, DE1 ready for operation

2: Speed = Speed reference value

3: Fault (DE1 not ready)

4: Speed > RO1 Upper Limit (P-52)

5: Motor current > RO1 Upper Limit (P-52)

6: Speed < RO1 Upper Limit (P-52)

7: Motor current < RO1 Upper Limit (P-52)

8: DE1 not enabled

9: Speed not at speed reference value

0

452.0 P-52 RO1 Upper Limit 0.0 ... 200.0 % 100.0 %

454.0 P-53 RO1 Hysteresis 0.0 ... 100.0 % 0.0 %

457.0 P-54 RO1 Switch-On

Delay

0.0 ... 250.0 s 0.0 s [www.eaton.eu](http://www.eaton.eu)

Application Note 11/2017 AP040036EN

PowerXL™

DE1 Variable Speed Starter

I/O Configuration

Level 2

1 – Fundamental – No previous experience necessary

2 – Basic – Basic knowledge recommended

3 – Advanced – Reasonable knowledge required

4 – Expert – Good experience recommended

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**Danger! - Dangerous electrical voltage!**

- Disconnect the power supply of the device.
- Ensure that devices cannot be accidentally restarted.
- Verify isolation from the supply.
- Cover or enclose any adjacent live components.
- Follow the engineering instructions (AWA/IL) for the device concerned.
- Only suitably qualified personnel in accordance with EN 50110-1/-2 (VDE 0105 Part 100) may work on this device/system.

• Before installation and before touching the device ensure that you are free of electrostatic charge.

• The functional earth (FE, PES) must be connected to the protective earth (PE) or the potential equalization.

The

system installer is responsible for implementing this connection.

• Connecting cables and signal lines should be installed so that inductive or capacitive interference does not

impair the automatic control functions.

• Suitable safety hardware and software measures should be implemented for the I/O interface so that an

open circuit on the signal side does not result in undefined states.

• Deviations of the mains voltage from the rated value must not exceed the tolerance limits given in the

specification, otherwise this may cause malfunction and/or dangerous operation.

• Emergency stop devices complying with IEC/EN 60204-1 must be effective in all operating modes. Unlatch-

ing of the emergency-stop devices must not cause a restart.

• Devices that are designed for mounting in housings or control cabinets must only be operated and controlled after they have been properly installed and with the housing closed.

• Wherever faults may cause injury or material damage, external measures must be

implemented to ensure

a safe operating state in the event of a fault or malfunction (e.g. by means of separate limit switches, mechanical interlocks etc.).

• Variable speed starters may have hot surfaces during and immediately after operation.

• Removal of the required covers, improper installation or incorrect operation of motor or variable speed

starter may destroy the device and may lead to serious injury or damage.

- The applicable national safety regulations and accident prevention recommendations must be applied to all work carried on live variable speed starters.
- The electrical installation must be carried out in accordance with the relevant electrical regulations (e . g. with regard to cable cross sections, fuses, PE).
- Transport, installation, commissioning and maintenance work must be carried out only by qualified personnel (IEC 60364, HD 384 and national occupational safety regulations).
- Installations containing variable speed starters must be provided with additional monitoring and protective devices in accordance with the applicable safety regulations. Modifications to the variable speed starters using the operating software are permitted.
- All covers and doors must be kept closed during operation.
- To reduce the hazards for people or equipment, the user must include in the machine design measures that restrict the consequences of a malfunction or failure of the variable speed starter (increased motor speed or sudden standstill of motor). These measures include:
  - Other independent devices for monitoring safety related variables (speed, travel, end positions etc.).
  - Electrical or non-electrical system-wide measures (electrical or mechanical interlocks).
  - Never touch live parts or cable connections of the variable speed starter after it has been disconnected from the power supply. Due to the charge in the capacitors, these parts may still be alive after disconnection. Consider appropriate warning signs.

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#### Disclaimer

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## 1 General

The variable speed starters of the series PowerXLTM DE1 are configured for many applications by default. In addition there is the possibility to adapt the devices to the application. Not only internal variables like ramp times or speed are changed, but also different functions can be assigned to the terminals. This possibility is universal inside the DE1 series and does not depend on the power rating.

This Application Note describes

- the existing input and output terminals
- the technical data
- the assignment of functions to terminals
- the configuration of the I/Os

Wiring diagram of a variable speed starter DE1 with default settings

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## 2 Hardware

All signals at the input terminal have the same signal common (0 V). Terminal 4 can be used as digital

input as well as analog input. The respective function depends on the configuration (see chapter 3ff).

### 2.1 Designation of the control terminals and technical data

Designation Function Default

0 V Signal common for all inputs (terminals. 1 ... 4) -

+ 10 V Control voltage and reference voltage

20 mA max.

Signal common: 0 V -

1 (DI1) Digital input 1 HIGH: 9 ... 30 V

10 V: 1,15 mA / 24 V: 3 mA FWD

2 (DI2) Digital input 2 HIGH: 9 ... 30 V

10 V: 1,15 mA / 24 V: 3 mA REV

3 (DI3) Digital input 3 HIGH: 9 ... 30 V

10 V: 0,12 mA / 24 V: 0,3 mA FF1

4 (AI1 / DI4) Analog input 1 or digital  
input 4

analog:

0 ... 10 V; 0,12 mA

0/4 ... 20 mA, RB = 500  $\Omega$

digital:

HIGH: 9 ... 30 V

10 V: 0,12 mA / 24 V: 0,3 mA

REF

(analog, 0 ... 10 V)

13 Relay RO1 (NO) 250 V, 6 A AC /

30 V, 5 A DC

RUN, device

enabled14

## 2.2 Wiring examples

The control terminals of the devices DE1 are fixed. On the variant DE11, the terminal block for the

control signals is pluggable. To apply control signals to the terminals, the internal 10 V as well as ex-

ternal voltages, e.g. 24 V from a PLC, can be used.

### 2.2.1 Example 1: Application motor starter

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### 2.2.2 Example 2: Application with variable speed

### 2.2.3 Example 3: Control voltage from an external voltage source

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### 2.2.4 Example 4: external reference value

### 2.2.5 Example 5: control by a PLC

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## 2.3 Relay output

Depending on the kind of load, we recommend the use of protection circuitry for the relay outputs.

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## 3 Configuration

The table gives an overview, how to determine the function of the single I/Os.

Designation

Selection / setting of

Function Format

(signal range)

## Scaling

(Gain) Inversion Hysteresis Offset

0 V fixed - - - - -

+10 V fixed - - - - -

1 (DI1)

P-12 / P-15

- - - - -

2 (DI2) - - - - -

3 (DI3) - - P-19 - -

4 (AI1 / DI4) P-16 P-17 P-18 - P-44

DE1: 13 fixed - - - - -

DE1: 14 -

DE11: 13 P-51 - - - P-52 / P-53

/ P-54 -

DE11: 14

### 3.1 Inputs

The function of the inputs can be configured in different ways:

- using the default settings.
- configuration with the configuration module DXE-EXT-SET. The numbers at the selector switch correspond to the settings of P-15 in terminal mode (P-12 = 0)
- via the optional keypad DX-KEY-LED
- via the parameter software DrivesConnect

The available terminal combinations depend on the selection of the "Local ProcessData Source" (P-

12). Default: P-15 = 0, P-12 = 0.

#### 3.1.1 Terminal configuration

PNU Parameter Name Range Default

423.0 P-15 DI Config Select 0 ... 9 0

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For the terminal functions the following abbreviations are used:

Abbreviation Function

DIR Used for the selection of the sense of rotation in connection with the START command.

Low = cw (FWD )

High = ccw (REV)

ATTENTION: in case of a wire break the drive reverses in case REV is selected! Alternative: use configuration with FWD/REV.

DOWN "Reduce speed" command, when a digital reference is selected. Used in combination with the command UP. In case UP and DOWN are applied simultaneously. The motor reduces its speed for the duration of the simultaneous signals with the deceleration ramp set with "t-dec" (P-04).

ENA Enable variable frequency drive. To start the drive an additional start signal (START, FWD, REV) is necessary. When removing ENA, the motor coasts to stop.

ENAINV In case ENAINV is used instead of ENA, the sense of rotation is inverted, compared to the one determined by a keypad or a fieldbus.

Example: ENA + FWD = FWD, ENAINV + FWD = REV

ENAREF Enable signal for the speed reference. This signal is necessary to operate the variable speed starter in addition to START respectively FWD/REV. At disconnection of ENAREF the variable speed starter ramps to stand still, but the variable speed starter will not be disabled.

EXTFLT External fault. Enables the inclusion of an external signal into the fault messages of the variable speed starter.

P-19 = 0: During operation a High signal must be applied to the terminal. A Low signal leads to a trip with the message "E-trip".

P-19 = 1: During operation a Low signal must be applied to the terminal. A High signal leads to a trip with the message "E-trip".

FF1 Selection between the analog speed reference at analog input AI1 (terminal 4) and the fixed frequency 1 (f-Fix1), set with P-20.

Low = analog reference, High = f-Fix1

FF20 / FF21 Selection of the fixed frequency with digital commands. The fixed frequencies f-Fix1 ... f-Fix4 are defined with P-20 ... P-23.

FF20 FF21

f-Fix1 (P-20) L L

f-Fix2 (P-21) H L

f-Fix3 (P-22) L H

f-Fix4 (P-23) H H

FWD START with a clockwise rotating field (FWD = Forward). When applying a High signal to the respective terminal, the motor accelerates with the predefined ramp. Removing the signal leads to a stop. The stop behavior depends on the setting of P-05 "Stop Mode". At standstill the variable speed starter is disabled. In applications with two directions, counter clockwise rotation is selected with REV. FWD and REV are logically connected (XOR). Applying both signals at the same time leads to a trip of the variable speed starter.

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Abbreviation Function

REF Analog input AI1 (terminal 4) is used as speed reference input.

P-16: Format (voltage input / current input ...)

P-17: Scaling

P-18: Inversion

REV START with a counter clockwise rotating field (REV = Reverse). When applying a High signal to the respective terminal, the motor accelerates with the predefined ramp. Removing the signal leads to a stop. The stop behavior depends on the setting of P-05 "Stop Mode". At standstill the variable speed starter is disabled. In applications with two directions, clockwise rotation is selected with FWD. FWD and REV are logically connected (XOR). Applying both signals at the same time leads to a trip of the variable speed starter.

START Starts and stops the motor. When applying a High signal to the respective terminal, the motor accelerates with the predefined ramp. Removing the signal leads to a stop. The stop behavior depends on the setting of P-05 "Stop Mode". At standstill the variable speed starter is disabled. In applications with two directions, the sense of rotation is selected with DIR or INV. In applications with Smartwire DT this signal is necessary in addition to the start command coming via bus. UP "Increase speed" command, when a digital reference is selected. Used in combination with the command DOWN. In case UP and DOWN are applied simultaneously. The motor reduces its speed for the duration of the simultaneous signals with the deceleration ramp set with "t-dec" (P-04).

### 3.1.2 Displaying input signals

The status of the inputs can be displayed by selecting the respective parameters.

PNU Parameter Name Range Default

560.0 P00-01 Analog input1 0.0 ... 100 % input signal - 550.0

...

550.3

P00-04 DI1 Status 0 / 1 -

The value, displayed with P00-01, takes also a potential scaling factor (P-17) into account.

Example:

$P00-01 = \text{Signal at AI1 [\%]} \cdot P-17$

The display on the keypad can be used to see the status of the digital inputs DI1 ... DI4. It starts with

DI1 on the left hand side of the display. 0 = Low signal, 1 = High signal at the respective input terminal.

Voltages between 9 and 30 V are identified as High signal. If an input is configured as analog input, its

status is displayed in P00-04 with 0 with voltage levels up to 9 V, above this with 1.

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### 3.1.3 Configuration of digital input DI3

Digital input 3 (Terminal 3) can be used to include an external signal into the fault messages. Parameter P-19 (DI3 Logic) determines, if a HIGH or a LOW signal is necessary at terminal 3 to indicate a proper status.

PNU Parameter Name Range Default

650.2 P-19 DI3 Logic 0 " HIGH = OK, LOW = fault

1 " LOW = OK, HIGH = fault 0

DI3 can be configured in a way, that a thermistor can be used to protect the connected motor. In this case P-19 must be set to 0.

Parameter P-15 has to be set in a way, that the function „External Fault“ (EXTFLT) is assigned to terminal 3 (DI3). During proper operation, a High-Signal is applied to terminal 3. In case of fault the temperature contact must open respectively the resistance of the thermistor has to increase. DE1 trips at a resistance of  $> 3.6 \text{ k}\Omega$ , Reset can be performed at values  $< 1.6 \text{ k}\Omega$ .

ATTENTION: Variable Speed Starters of the series DE1 are designed according IEC / EN 61800-5-1,

which requires double isolation between mains circuits and circuits with low voltage. Inside the drive

power part and control part are separated accordingly. In case temperature sensors inside the motor

are connected to DE1, the sensors have to be double isolated against the motor windings, not to

weaken the overall insulation system!

In applications with fire mode (P-45 = 1...4) digital input DI3 is used to apply the fire mode signal to

the variable speed starter. Parameter P-19 (DI3 Logic) is not effective in this case. Further information about fire mode is available in application note AP040181EN “DE1 Fire Mode”.

### 3.1.4 Configuration of analog input AI1

At analog input AI1 (terminal 4) it is also possible to take a scaling factor into account.

- Signal range: Selection of the kind of signal at the analog input. The maximum value of the signal corresponds to the maximum speed / frequency set with P-01.

- Gain: With the gain the analog input can be scaled.

- AI1 Invert:

P-18 = 0 " 0 V = minimum frequency, 10 V = maximum frequency

P-18 = 1 " 0 V = maximum frequency, 10 V = minimum frequency

- Offset AI1:

With P-44 an offset to the signal at analog input AI1 can be set. It is adjustable in the range between -1.000 and + 1.000. It must be noted, that a negative offset value will be added to the one at AI1, a positive one will be subtracted. Example: P-44 = -0.2 " 20 % of the full scale

value are added to the signal coming from AI1. The gain, set with P-17, is also effective for the offset signal.

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PNU Parameter Name Range Default

260.0 P-16 AI1 Signal Range

0: 0 ... 10 V (U 0–10)

1 : 0 ... 20 mA (A 0–20)

2: t 4 ... 20 mA (trip in case of wire break) (t 4–20)

3: r 4 ... 20 mA (ramps to f-Fix1 (P-20) in case of wire break) (r 4–20)

0

261.0 P-17 AI1 Gain 0.100 ... 2.500 1.000

267.0 P-18 AI1 Invert 0 = no inversion

1 = inversion 0

262.0 P-44 AI1 Offset -1.000 ... +1.000 0

3.2 Relay output

The function of the output relay between the terminals 13 and 14 of the devices DE1 is fixed (RUN).

The contact closes when

- the device is supplied
- no fault message is present
- the start signal is applied (FWD/REV/START)

The contact opens

- at disconnection of the supply voltage
- in case of a fault
- when removing the start signal where the point of opening depends on the selected „Stop Mode“:

o P-05 = 0 " coasting. The contact opens as soon as the start signal is removed.

o P-05 = 1 " ramping. The contact opens when the motor is at stand still after a deceleration with the ramp set with „t-dec“ (P-04).

On variants DE11 the function of the relay contact can be configured.

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3.2.1 Selecting the function of RO1 (DE11 only)

The function of relay RO1 (terminals 13 and 14) can be selected with parameter P-51.

For the settings P-51 = 4 ... 7, switch on threshold level (P-52) and a hysteresis of the relay (P-53) can be defined.

Switch OFF threshold = „RO1 Upper Limit“ (P-52) – „RO1 Hysteresis“ (P-53)

P-51 = 4 or 5: output will be logic 1 if the value > „RO1 Upper Limit“ , output will be logic 0 if value < Switch OFF threshold

P-18 = 6 or 7: output will be logic 0 if the value > "RO1 Upper Limit" , output will be logic 1 if value < Switch OFF threshold

P-55 defines a switch-on delay, before the relay switches from logic 0 to logic 1.

PNU Parameter Name Range Default

451.0 P-51 RO1 Function 0: RUN, enable (FWD/REV)

1: READY, DE1 ready for operation

2: Speed = Speed reference value

3: Fault (DE1 not ready)

4: Speed > RO1 Upper Limit (P-52)

5: Motor current > RO1 Upper Limit (P-52)

6: Speed < RO1 Upper Limit (P-52)

7: Motor current < RO1 Upper Limit (P-52)

8: DE1 not enabled

9: Speed not at speed reference value

0

452.0 P-52 RO1 Upper Limit 0.0 ... 200.0 % 100.0 %

454.0 P-53 RO1 Hysteresis 0.0 ... 100.0 % 0.0 %

457.0 P-54 RO1 Switch-On

Delay

0.0 ... 250.0 s 0.0 s Application Note 07/2022 AP040184EN

PowerXL DG1 – Firmware Update

Level 3

1 – Fundamental – No previous experience necessary

2 – Basic – Basic knowledge recommended

3 – Advanced – Reasonable knowledge required

4 – Expert – Good experience recommended

2 Application Note Firmware Update DG1 07/2022 AP040184EN Eaton.com

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Original Application Note

Original document is the German version of this document.

Translation

All non-German language versions of this document are translations of the original application note.

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**DANGER!**

**DANGEROUS ELECTRICAL VOLTAGE!**

- Disconnect the power supply of the device.
- Ensure that devices cannot be accidentally restarted.
- Verify isolation from the supply.
- Ground and short-circuit.
- Cover or enclose any adjacent live components.
- Follow the engineering instructions (AWA/IL) for the device concerned.
- Only suitably qualified personnel in accordance with EN 50110-1/-2 (VDE 0105 Part 100) may work on this device/system.
- Before installation and before touching the device ensure that you are free of electrostatic charge.
- The functional earth (FE, PES) must be connected to the protective earth (PE) or the potential equalization.

The

system installer is responsible for implementing this connection.

- Connecting cables and signal lines should be installed so that inductive or capacitive interference does not impair the automatic control functions.
- Suitable safety hardware and software measures should be implemented for the I/O interface so that an open circuit on the signal side does not result in undefined states.
- Deviations of the mains voltage from the rated value must not exceed the tolerance limits given in the specification, otherwise this may cause malfunction and/or dangerous operation.
- Emergency stop devices complying with IEC/EN 60204-1 must be effective in all operating modes. Unlatching of the emergency-stop devices must not cause a restart.
- Devices that are designed for mounting in housings or control cabinets must only be operated and controlled after they have been properly installed and with the housing closed.
- Wherever faults may cause injury or material damage, external measures must be implemented to ensure a safe operating state in the event of a fault or malfunction (e.g. by means of separate limit switches, mechanical interlocks etc.).
- The used device may have hot surfaces during and immediately after operation.
- Removal of the required covers, improper installation or incorrect operation of motor or device may destroy

the device and may lead to serious injury or damage.

- The applicable national safety regulations and accident prevention recommendations must be applied to all work carried on live device.
- The electrical installation must be carried out in accordance with the relevant electrical regulations (e. g. with regard to cable cross sections, fuses, PE).
- Transport, installation, commissioning and maintenance work must be carried out only by qualified personnel (IEC 60364, HD 384 and national occupational safety regulations).
- Installations containing device must be provided with additional monitoring and protective devices in accordance with the applicable safety regulations. Modifications to the device using the operating software are permitted.
- All covers and doors must be kept closed during operation.
- To reduce the hazards for people or equipment, the user must include in the machine design measures that restrict the consequences of a malfunction or failure of the device (increased motor speed or sudden standstill of motor). These measures include: – Other independent devices for monitoring safety related variables (speed, travel, end positions etc.). – Electrical or non-electrical system-wide measures (electrical or mechanical interlocks). – Never touch live parts or cable connections of the device after it has been disconnected from the power supply. Due to the charge in the capacitors, these parts may still be alive after disconnection. Consider appropriate warning signs.

4 Application Note Firmware Update DG1 07/2022 AP040184EN Eaton.com

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General

The device software of the DG1 can be updated to a newer version or downgraded to an old  
one.

Both is done via the so-called firmware update tool.

Connecting the Drive to a PC

1. Remove the front cover.
2. Connect the programming cable to terminals 25 and 26.

Abbildung 1: Connecting the programming cable

Apply main voltage

Start the drive by applying the main voltage. Depending on frame size:

230V AC à single phase: L1(L)/L3(N)

400V AC à three phase: L1/L2/L3

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Firmware Upgrade

1. First download the desired firmware package from the Eaton website and unzip the file.

Abbildung 2: Firmware package

2. Open the Firmware Upgrade Tool.

Abbildung 3: Firmware Upgrade Tool

3. Select the previously downloaded firmware package from your directory by clicking "Browse".

Abbildung 4: Power Xpert inControl Software

4. Select the file "DG1\_C0033".

Abbildung 5: DG1\_C0033

5. Check the cable connection and the COM port in the Windows Device Manager.

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Abbildung 6: Device Manager

6. Enter "1" for "Slave Address" and select the COM port.

Abbildung 7: Settings

7. Establish the connection via "Connect".

Abbildung 8: Establish connection

8. After the firmware has been detected, a dialog for confirming the firmware package is displayed. The tool automatically sets check marks once the version differences have been detected.

Abbildung 9: Update process

9. Choose „Block 0“ for german and „Block 1“ for english.

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Abbildung 10: Update process

10. Confirm the selection with „Program“.

Abbildung 11: Confirming

11. Verify that the update has been completed correctly. ("Programming Success - Verification

OK"). If "Verification OK" appears, select "Disconnect". If "Failed" appears, repeat the update

process or contact After Sales Service.

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Abbildung 12: Update completed

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Resetting to default settings

Reset all parameter to the factory settings by proceeding as follows:

Parameters à Basic Settings à System à Parameter Sets (P21.1.3)

Then select "Reload defaults".

Abbildung 13: Parameter reset

Now the firmware update is completed. You can disconnect the programming cable, remove the

power connector and reattach the front cover.

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Firmware Upgrade for optional cards

1. Connect the optional module to one of the expansion slots.

Abbildung 14: Installing expansions

2. Follow the steps 2.1 to 4.8.

3. Confirm the selection with „Program“.

Abbildung 15: Confirming the selection

4. Check the update version of the board. If "Code is same" appears, no update needs to be performed here.

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Abbildung 16: Check the version

5. Click „Disconnect“ to disconnect the communication again.

If the drive now remains in "Loader Mode", a connection should be established again via "Connect"

and then disconnected again via "Disconnect".

If the drive is still in "Booth Loader Mode" and the "Startup Wizard" does not appear, please contact

After Sales Service.

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Application Note 04/2017 AP040168EN

PowerXL™

DG1 Variable Frequency Drives

Load balancing in multi motor applications

Level 1

- 1 – Fundamental – No previous experience necessary
- 2 – Basic – Basic knowledge recommended
- 3 – Advanced – Reasonable knowledge required
- 4 – Expert – Good experience recommended

2017-04-25

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AP040168EN DG1 Load balancing in multi motor applications Page 3

**Danger! - Dangerous electrical voltage!**

- Disconnect the power supply of the device.
  - Ensure that devices cannot be accidentally restarted.
  - Verify isolation from the supply.
  - Cover or enclose any adjacent live components.
  - Follow the engineering instructions (AWA/IL) for the device concerned.
  - Only suitably qualified personnel in accordance with EN 50110-1/-2 (VDE 0105 Part 100) may work on this device/system.
  - Before installation and before touching the device ensure that you are free of electrostatic charge.
  - The functional earth (FE, PES) must be connected to the protective earth (PE) or the potential equalization.
- The system installer is responsible for implementing this connection.
- Connecting cables and signal lines should be installed so that inductive or capacitive interference does not impair the automatic control functions.
  - Suitable safety hardware and software measures should be implemented for the I/O interface so that an open circuit on the signal side does not result in undefined states.
  - Deviations of the mains voltage from the rated value must not exceed the tolerance limits given in the specification, otherwise this may cause malfunction and/or dangerous operation.
  - Emergency stop devices complying with IEC/EN 60204-1 must be effective in all operating

modes. Unlatch-

ing of the emergency-stop devices must not cause a restart.

- Devices that are designed for mounting in housings or control cabinets must only be operated and controlled after they have been properly installed and with the housing closed.
- Wherever faults may cause injury or material damage, external measures must be implemented to ensure a safe operating state in the event of a fault or malfunction (e.g. by means of separate limit switches, mechanical interlocks etc.).
- Frequency inverters may have hot surfaces during and immediately after operation.
- Removal of the required covers, improper installation or incorrect operation of motor or frequency inverter may destroy the device and may lead to serious injury or damage.
- The applicable national safety regulations and accident prevention recommendations must be applied to all work carried on live frequency inverters.
- The electrical installation must be carried out in accordance with the relevant electrical regulations (e. g. with regard to cable cross sections, fuses, PE).
- Transport, installation, commissioning and maintenance work must be carried out only by qualified personnel (IEC 60364, HD 384 and national occupational safety regulations).
- Installations containing frequency inverters must be provided with additional monitoring and protective devices in accordance with the applicable safety regulations. Modifications to the frequency inverters using the operating software are permitted.
- All covers and doors must be kept closed during operation.

To reduce the hazards for people or equipment, the user must include in the machine design measures that restrict the consequences of a malfunction or failure of the frequency inverter (increased motor speed or sudden standstill of motor). These measures include: – Other independent devices for monitoring safety related variables (speed, travel, end positions etc.).  
– Electrical or non-electrical system-wide measures (electrical or mechanical interlocks).  
– Never touch live parts or cable connections of the frequency inverter after it has been disconnected from the power supply. Due to the charge in the capacitors, these parts may still be alive after disconnection. Consider appropriate warning signs.

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AP040168EN DG1 Load balancing in multi motor applications Page 4

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AP040168EN DG1 Load balancing in multi motor applications Page 5

### 1 General

In cases, in which multiple motors are fixed permanently or coupled via friction, an equal load shar-

ing between the motors is required. Already small differences in the mechanical structure of the

drives inside the system or manufacturing tolerances can lead to an unbalanced load sharing. Beside

an oversizing other measures exist to balance the load to ensure a reliable operation of the

application and to prevent overload situations for single motors. Like in many other cases, multiple solutions exist, differing in complexity and costs. There is a fundamental interest to choose the variant with the best value for money. In the end the application determines, which kind of solution can be chosen. This application note describes three of the possible solutions in connection with variable frequency drives and provides an indication of the right solution.

The following chapters describe, how the different solutions work. The table below gives an overview

about the substantial features and differences.

Control via slip Droop function Torque control

Control mode Speed control Speed control

1 motor with speed control, the other ones

with torque control

Number of variable frequency drives

1 variable frequency drive per motor; connecting multiple motors in parallel to the output of one device is possible.

1 variable frequency drive per motor

1 variable frequency drive per motor

Load balancing via Slip Load dependent corrective value Torque control

Accuracy of balancing + ++ +++

Motors

(power, manufacturer)

Equal motors necessary

Different motors possible

Different motors possible

Mechanical coupling between the motors

Preferably coupled via friction; fixed mechanical coupling possible in some applications.

Preferably coupled via friction; fixed mechanical coupling possible in some applications.

Fixed coupling and coupling via friction possible. In case of coupling via friction a speed limitation is recommended.

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AP040168EN DG1 Load balancing in multi motor applications Page 6

## 2 Load balancing via slip

The speed of a three phase induction motor depends on the load. When it is supplied with the voltage and frequency according to its name plate, an unloaded motor turns with nearly synchronous speed, while the speed at rated load corresponds to the rated speed. In case of a 50 Hz mains supply and a four pole motor this means, that the unloaded motor turns with approximately 1500 rpm and at rated load e.g. with 1470 rpm. The difference between synchronous speed and the speed of the motor axis is called slip.

In the example on the left the motor is loaded with torque  $M_1$  and it turns with the speed  $n_1$ . The load is increased up to  $M_2$  j " The speed drops down to  $n_2$  k.

This behavior is utilized in a slip dependent load balancing. This simplest kind of "automatic" load

sharing presumes, that the mechanics as well as the motors of all parts of the system are identical. In

theory all motors have to carry the same load per definition, but tolerances, temperature dependen-

cy and small mechanical differences let the loads drift apart, even when the motors were equally

loaded at the point of start.

But how does load balancing work? The motor with the highest load drops in speed and in this case

the other one(s) have to carry more load than before. The load is now more or less balanced. There is

no possibility for load adjustment and the sharing is defined by the system. Therefore it makes sense

to add some margin when calculating the motor powers.

The variable frequency drive DG1 has to work in the motor control mode “Freq Control” (P8.1 = 0). In

case each motor has its own variable frequency drive, they must have identical parameter settings.

Parameter Name Range Default

P8.1 Motor Control Mode Freq Control (0)

Speed Control (1)

Open Loop Speed Control (5)

Open Loop Torque Control (6)

Freq Control (0)

It is also possible to connect multiple motors in parallel to one variable frequency drive. It has to be

noted, that each motor must have its own motor protection, because the total current is “known” by

the variable frequency drive, but not how it is shared between the single motors.

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AP040168EN DG1 Load balancing in multi motor applications Page 7

3 Load balancing via drooping

In case speed controlled drive systems are mechanically connected through form fit or friction, the

fastest drive takes the load and pulls the other ones, which are less, or in extreme cases, not loaded.

To counteract this effect, the speed reference will be corrected, depending on the load. At load in-

crease, the droop function reduces the resulting speed reference (set reference – speed reduction),

the motor falls back a little bit in its speed and the other motors inside the system take more load

automatically.

Application experience shows, that it is of advantage in many cases to have one motor inside the

system, where the droop function is disabled (P8.13 “Load Drooping” = 0.00 %), while it is enabled

(P8.13 “Load Drooping” different from 0.0 %) for all other motors inside the system. The set value of

P8.13 is the percentage of speed by which the speed drops in case the motor is loaded with rated

torque. With reduced load, the speed reduction will be reduced accordingly.

In exceptional cases it can also be advantageous to enable the droop function for all motors.

The variable frequency drive DG1 has to work in the motor control mode “Open Loop Speed Control”

(P8.1 = 5) to achieve the best result.

Parameter Name Range Default

P8.1 Motor Control Mode Freq Control (0)

Speed Control (1)

Open Loop Speed Control (5)

Open Loop Torque Control (6)

Freq Control (0)

P8.13 Load Drooping 0.00 % ... 100.00 % 0.00 %

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AP040168EN DG1 Load balancing in multi motor applications Page 8

### 3.1 Application example

Material is transported through the machine by means of two conveyor belts. Each belt is driven by its own

motor. Because of the contact pressure, the two belts are connected mechanically. In case one of the two mo-

tors tries to run a little bit faster than the other one, it leads to an unequal load sharing.

Without an enabled droop function, motor 1 takes 80 % of its rated load, motor 2 85 %.

Because of the higher

load, motor 2 becomes warmer than motor 1, possibly one can also see the difference in speed on the material

which is transported between the belts.

Now the droop function will be enabled with P8.13. The system will change to equal load sharing iteratively.

Values at the beginning (we are looking to the system at an output frequency of 40 Hz, P1.9 = 50 Hz, P8.13 =

10.00 %):

Resulting speed of motor 1:  $40 \text{ Hz} - ((10 \% \cdot 50 \text{ Hz}) \cdot 80 \%) = 36 \text{ Hz}$

Resulting speed of motor 2:  $40 \text{ Hz} - ((10 \% \cdot 50 \text{ Hz}) \cdot 85 \%) = 35,75 \text{ Hz}$

Motor 2 now runs slower than motor 1 " The load of motor 1 increases " Therefore the load of motor 2 is

reduced ..... . This is a repetitive process until an equal sharing of the load is achieved.

Remaining differences

in load can be adjusted with 8.13.

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AP040168EN DG1 Load balancing in multi motor applications Page 9

### 4 Adjustable load balancing via torque control

Inside this system, one motor is speed controlled and the other one(s) torque controlled.

The speed

controlled motor determines the speed of the system, while the torque is the control variable for the

other motors. Here it is possible to use motors of different ratings and it is also possible to set indi-

vidual shares of the load. A torque control is much more complex than the principles described in

chapters 2 and 3. On the other hand you have much more possibilities to adopt the control to the

application, which results in a higher accuracy. Nevertheless the other principles are useful in simple applications because of their simplicity and value for money.	
Torque control is extensively described inside the application Note „AP040167EN Torque Control”.	
Please refer to this document.	
One important aspect must be mentioned here: A torque controlled motor always tries to bring the required torque (or tension in case of linear movements) to the load. When this is not possible, the torque is used for acceleration to the maximum possible speed. This is not critical as long as the motors are connected together mechanically, e.g. when all pinions work on the same geared ring. In cases where the speeds of the motors involved are not synchronized mechanically and a slip in speed is possible, it is strongly recommended to limit the speed of the torque controlled motor.	
The necessary aspects and settings are comprehensively described in the application note AP040167EN mentioned above. <a href="http://www.eaton.eu">www.eaton.eu</a>	
Application Note 01/2018 AP040177EN	
DE	
PowerXL™	
DG1 Variable Frequency Drives	
Motor data and V/f curves	
Level 2	
1 – Fundamental – No previous experience necessary	
2 – Basic – Basic knowledge recommended	
3 – Advanced – Reasonable knowledge required	
4 – Expert – Good experience recommended	
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AP040177EN DG1 Motor data and V/f curves Page 3

Danger! - Dangerous electrical voltage!

- Disconnect the power supply of the device.
- Ensure that devices cannot be accidentally restarted.
- Verify isolation from the supply.
- Cover or enclose any adjacent live components.
- Follow the engineering instructions (AWA/IL) for the device concerned.
- Only suitably qualified personnel in accordance with EN 50110-1/-2 (VDE 0105 Part 100) may work on this device/system.
- Before installation and before touching the device ensure that you are free of electrostatic charge.
- The functional earth (FE, PES) must be connected to the protective earth (PE) or the potential equalization.

The

system installer is responsible for implementing this connection.

- Connecting cables and signal lines should be installed so that inductive or capacitive interference does not impair the automatic control functions.
- Suitable safety hardware and software measures should be implemented for the I/O

interface so that an

open circuit on the signal side does not result in undefined states.

- Deviations of the mains voltage from the rated value must not exceed the tolerance limits given in the

specification, otherwise this may cause malfunction and/or dangerous operation.

- Emergency stop devices complying with IEC/EN 60204-1 must be effective in all operating modes. Unlatch-

ing of the emergency-stop devices must not cause a restart.

- Devices that are designed for mounting in housings or control cabinets must only be operated and con-

trolled after they have been properly installed and with the housing closed.

- Wherever faults may cause injury or material damage, external measures must be implemented to ensure

a safe operating state in the event of a fault or malfunction (e.g. by means of separate limit switches, me-

chanical interlocks etc.).

- Frequency inverters may have hot surfaces during and immediately after operation.

- Removal of the required covers, improper installation or incorrect operation of motor or frequency invert-

er may destroy the device and may lead to serious injury or damage.

- The applicable national safety regulations and accident prevention recommendations must be applied to

all work carried on live frequency inverters.

- The electrical installation must be carried out in accordance with the relevant electrical regulations (e. g.

with regard to cable cross sections, fuses, PE).

- Transport, installation, commissioning and maintenance work must be carried out only by qualified per-

sonnel (IEC 60364, HD 384 and national occupational safety regulations).

- Installations containing frequency inverters must be provided with additional monitoring and protective

devices in accordance with the applicable safety regulations. Modifications to the frequency inverters us-

ing the operating software are permitted.

- All covers and doors must be kept closed during operation.

To reduce the hazards for people or equipment, the user must include in the machine design measures that

restrict the consequences of a malfunction or failure of the frequency inverter (increased motor speed or sud-

den standstill of motor). These measures include: – Other independent devices for monitoring safety related

variables (speed, travel, end positions etc.).

– Electrical or non-electrical system-wide measures (electrical or mechanical interlocks).

– Never touch live parts or cable connections of the frequency inverter after it has been

disconnected from the power supply. Due to the charge in the capacitors, these parts may still be alive after disconnection. Consider appropriate warning signs.

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#### 1 General

Devices of the series PowerXL™ DG1 are variable frequency drives for the supply of three phase in-

duction motors. By default they are configured, that motors of the respective power class can be

supplied without changing the settings. Many standard cases can be covered.

There are some applications, which require an adaptation by changing parameters. In this Applica-

tion Note the following aspects are covered:

- Selection of the motor control mode
- Adaptation to the connected motor
- Slip compensation
- Setting the V/f curve

#### 2 Motor data

Condition for a proper operation is the right connection (star / delta) of the motor to the output ter-

minals of the device. The rated voltage of the motor windings is decisive.

Device Output Voltage Motor Connection

DG1-32... 3 x 230 V 230 / 400 V Delta

DG1-34... 3 x 400 V 230 / 400 V

400 / 660 V

Star

Delta

DG1-34... 3 x 400 V 230 / 400 V Delta

Special case: 87 Hz-curve (see section 4.2 )

An adaptation to the connected motor can be done with the following parameters:

- P1.6 Motor Nom Speed
- P1.7 Motor PF
- P1.8 Motor Nom Voltage
- P1.9 Motor Nom Frequency

The respective values can be taken from the name plate of the motor or from the data sheet of the

motor manufacturer. They are used for the setting of the motor protection and define the V/f curve.

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## 2.1 Motor Nom Current

Parameter P1.5 „Motor Nom Current“ is set to the rated current  $I_e$  of the variable frequency drive by

default. At the same time it is the set value for the thermal protection of the motor. In case the mo-

tor has a nominal current different to the one of the VFD, P1.5 must be set accordingly to ensure

motor protection.

It must be pointed out, that this current value is set, which is assigned to the type of connection of

the motor. In the example above it is 3,2 A at 230 V (Delta) respectively 1,9 A at 400 V (Star).

Parameter Name Range Default

P1.5 Motor Nom Current  $0,1 \cdot I_e \dots 2 \cdot I_e$

$I_e$  = Rated current of the variable frequency drive

All measures to protect the connected motor are described in the Application Note

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“Starting, stopping and operation”.

## 2.2 Motor Nom Speed

The setting of P1.6 „Motor Nom Speed“ is necessary for three reasons:

- to display the right speed value in all modes of operation
- for calculation of the slip compensation in operation mode “Speed Control” (P8.1 = 1)
- for calculations inside the motor model when operating in vector mode (P8.1 = 5 „Open Loop

## Speed Control“

Please use the name plate value for setting P1.6.

Parameter Name Range Default

P1.6 Motor Nom Speed 300 ... 20000 rpm 1750 rpm

### 2.3 Motor PF

In vector mode (P8.1 = 5 „Open Loop Speed Control“) the power factor ( $\cos \phi$ ), which is specified on

the motor's name plate, must be set.

Parameter Name Range Default

P1.7 Motor PF 0.3 ... 1 0.85

### 2.4 Motor Nom Voltage

Motor rated voltage (name plate) taking the connection (star / delta) into account.

In exceptional cases, a different setting of P1-07 is necessary. See section 4.2 “87 Hz curve”

Parameter Name Range Default

P1.8 Motor Nom Voltage 180 ... 690 V U<sub>e</sub>

U<sub>e</sub> = Rated voltage of the variable frequency drive, e.g. 230 V or 400 V depending on the device type

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### 2.5 Motor Nom Frequency

Rated frequency of the motor. By default this parameter is set to the mains frequency (50 Hz in Eu-

rope, 60 Hz in USA) and doesn't need to be changed in the majority of cases.

In case, motors with rated frequencies different from the mains frequency (e.g. 200 Hz for fast rotat-

ing motors) or if the 87 Hz curve is used (see section 4.2), P1.9 has to be set accordingly.

When changing the value of P1.9 the setting of P8.5 “Field Weakening Point” is set to the same value.

If the application requires different values for P1.9 and P8.5, Motor Nom Frequency must be set first,

before adopting the value for the field weakening point

Parameter Name Range Default

P1.9 Motor Nom Frequency 0.00 ... 400.00 Hz 50 Hz

### 2.6 Motor Identification

The motor identification MUST be performed in vector mode (P8.1 = 5 or 6) to gain the required pa-

rameter values for an optimal performance of the motor.

ATTENTION: The motor data (e.g. the resistance) change with the temperature. Therefore the motor

identification run shall be performed with a warm motor.

The kind of motor identification run is determined by the setting of P8.14 „Identification“.

The fol-

lowing motor data are identified:

- Motor Stator Resistance R1 (P8.50)

- Motor Rotor Resistance R2 (P8.51)
- Motor Leak Inductance X1 (P8.52)
- Motor Mutual Inductance Xh (P8.53)
- Motor Excitation Current (P8.54)

P8.14 = 0: No Action

No identification of the motor data will be performed. This is the setting during normal operation of the drive.

P8.14 = 1: Identification Only Stator Resistor

During the identification run only the stator resistance is identified. The other values remain unchanged.

P8.14 = 2: Identification with Run

The values for the parameters P8.50 up to P8.54 are identified. The measurement is done with a running motor. The motor must be unloaded (load decoupled, no gearbox ...).

P8.14 = 3: Identification No Run

The values for the parameters P8.50 up to P8.54 are identified. During the measurement the motor is standing still.

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How to perform a motor identification run:

- Before starting a motor identification run, the motor data (parameters P1.5 up to P1.9) must be set.
- Select the motor control mode P8.1 = "3: Open Loop Speed Control".
- Select in P8.14 „Identification“, which kind of identification shall be performed (P8.14 = 1...3).
- Remove any connection between the drive and a PC during identification run.
- Apply START command
- The identification of the motor data takes place automatically and is active for about 30 s respectively until the START signal will be removed.
- On the keypad „Motor Identification“ is shown.
- The motor data are identified and assigned to the respective parameters.
- In case an identification is not possible, the fault message "Motor ID Fault" (#57) is displayed.

One reason could be that the rated power of the connected motor deviates too much from the one of the variable frequency drive. Alternatively the motor data can be set manually on the basis of technical information supplied by the motor manufacturer.

· After a motor identification run, the START signal must be reapplied to start the motor. The motor doesn't start automatically, even when the START signal is still applied to the respective terminal.

· Parameter P8.14 “Identification” is reset to “0: No action” automatically as soon as the identification run is finished.

Parameter Name Range Default

P8.14 Identification 0: No Action

1: Identification Only Stator Resistor

2: Identification with Run

3: Identification No Run

0: No Action

P8.50 Stator Resistor 0.001 ... 65535 W 0.033 W

P8.51 Rotor Resistor 0.001 ... 65535 W 0.034 W

P8.52 Leak Inductance 0.01 ... 655.35 mH 0.12 mH

P8.53 Mutual Inductance 0.1 ... 6553.5 mH 3.4 mH

P8.54 Excitation Current 0.1 ... 7.4 A 0.1 A

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3 Motor Control Mode

Parameter P8.1 „Motor Control Mode“ determines the way, how the motor is controlled (e.g. frequency or vector control). The information given inside the Application Note refer to the settings

P8.1 = 0, 1 or 5.

By default the variable frequency drive is configured for Frequency Control (P8.1 = 0), which is mainly

used in simple applications. With speed control (P8.1 = 1 or 5) an improved speed accuracy and a

better torque performance can be achieved. In this case the motor data must be set and with Open

Loop Speed Control (P8.1 = 5) a motor identification run (P8.14, see section 2.6) is necessary.

Parameter Name Range Default

P8.1 Motor Control Mode 0: Frequency Control

1: Speed Control

5: Open Loop Speed Control

6: Open Loop Torque Control

0

3.1 Frequency Control (V/f)

P8.1 = 0

The output frequency of the variable frequency drive is proportional to the reference, which is for

example applied to an analog input. The ratio between the output voltage and the frequency is kept

constant. This leads to a speed change when the load is changing, like with a single speed motor

connected DOL to the mains.

This control mode is preferred, when multiple motors are connected in parallel at the output of one

single variable frequency drive respectively in simple applications, where no special requirements

concerning speed accuracy at variable load exist.

### 3.2 Speed Control

P8.1 = 1

In principle the Speed Control works like the Frequency Control described in section 3.1. At Speed

Control the slip compensation is activated in addition, which takes care, that the motor speed is kept

approximately constant even in case of load changes. In this motor control mode the motor data

must be set (P1.5 up to P1.9)

The slip is the difference between a synchronous speed because of a rotating field and the actual

speed of the motor. The name plate in section 2 shows a rated speed of 1410 rpm. It is a 4 pole mo-

tor with a synchronous speed of 1500 rpm. Between no load and rated load there is a slip of 90 rpm.

Running the motor with a variable frequency drive, one wants to prevent the speed variance by

compensating the slip.

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with slip compensation without slip compensation

With slip compensation: at load increase j voltage and frequency are increased accordingly k. The

speed  $n_1$  remains constant. At load decrease voltage and frequency are reduced.

Without slip compensation: with load j the speed drops from  $n_1$  to  $n_2$  k, when unloading the speed

increases again.

### 3.3 Open Loop Speed Control

P8.1 = 5

Open loop means, that a feedback of the motor speed to the variable frequency drive, e.g. by using

an encoder, is not required. The speed information used in the control algorithm is the result of a

calculation by the motor model. To ensure an optimal performance, the motor data (parameters P1.5

up to P1.9) must be set and a motor identification run must be performed (see section 2.6). Speed

accuracy and torque performance are improved compared to the motor control mode

“Speed Con-

trol” described in section 3.2.

Note: When multiple motors are connected in parallel to one single variable frequency drive, this

motor control mode may not be used!

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4 V/f curve

The V/f curve determines the magnetization of the motor and therefore the torque behavior signifi-

cantly. In addition the energy efficiency of the complete system can be impacted.

As described in section 3, multiple motor control modes exist. Common to all of them is, that the

field weakening point (FWP) and the maximum frequency must be defined. In case of open loop

speed control (P8.1 = 5), the variable frequency drive calculates the necessary settings on the basis

of this information and the determined motor data. In case of frequency control (P8.1 = 0) or speed

control with slip compensation (P8.1 = 1) it is possible to modify the V/f curve to improve the torque

behavior (see section 4.1).

· P1.2 „Max Frequency“

maximum frequency for the application. This frequency may be above the „Motor Nom Frequency“ (P1.9).

· P8.5 „Field Weakening Point“

This parameter defines the frequency, at which the maximum output voltage, defined with P8.6, is reached.

· P8.6 „Voltage at FWP“

Maximum voltage of the variable frequency drive in percent of the Motor Nom Voltage (P1.8). This voltage is reached at the field weakening point (FWP) defined with P8.5.

Note: At a change of parameter P1.9 „Motor Nom Frequency“ P8.5 is automatically set to the same

frequency value. In applications, where the frequency at FWP is different to the Motor Nom Fre-

quency, P1.9 must be set first, before setting P8.5. The same is true for the voltage. Here P1.8 “Mo-

tor Nom Voltage” must be set before P8.6 “Voltage at FWP”.

Parameter Name Range Default

P1.2 Max Frequency P1.1 ... 400 Hz 50.0 Hz

P8.5 Field Weakening Point 8.0 Hz ... P1.2 P1.9

P8.6 Voltage at FWP 10 ... 200 % – P1.8 P1.8

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#### 4.1 Optimizing the V/f curve at Frequency Control and Speed Control

The V/f curve shown in section 4 is idealized (P8.4 = 0 "Linear") and sufficient for many applications.

There are two cases, where the shape of the V/f curve should be adopted:

- where a higher starting torque is required, respectively where the motor has to run at lower

speed stationary

- in pump and fan applications, where the motor losses shall be reduced by field weakening under part load conditions.

The different shapes of the V/f curve can be selected with P8.4 "V/Hz Ratio".

- P8.4 = 0 „Linear“

Voltage and frequency change linearly from zero up to the field weakening point (FWP)

- P8.4 = 1 „Squared“

Voltage and frequency change squared from zero up to the field weakening point (FWP).

See

also section 4.1.2.

- P8.4 = 2 „Programmable“

The shape of the curve can be configured, see also section 4.1.1-

- P8.4 = 3 „Linear + Flux Optimization“

The shape of the V/f curve is adopted to the load conditions automatically, see also section 4.1.2.

Parameter Name Range Default

P8.4 V/Hz Ratio 0: Linear

1: Squared

2: Programmable

3: Linear + Flux Optimization

0: Linear

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##### 4.1.1 Improving the torque behavior

When operating with lower speeds, the voltage drop inside the motor becomes particularly noticeable-

ble, which leads to a reduced speed, unbalanced run and in extreme cases to a standstill of the motor

with current flow at the same time. This effect can be reduced by increasing the output voltage in the

lower speed range. P8.3 "V/Hz Optimization" determines, in which way this will be achieved:

- P8.3 = 1 „Enabled“

The voltage is increased automatically. The value depends on the motor rating and the values

are based on experience. Setting:

- o Set motor data in parameter group 1 (P1.5 up to P1.9)

- o P8.3 = 1: Enabled

- P8.3 = 0 „Disabled“

The shape of the V/f curve can be configured manually. In this case P8.4 „V/Hz Ratio“ has to be set to „2: Programmable“.

- P8.7 „V/Hz Mid Frequency“
- P8.8 „V/Hz Mid Voltage“
- P8.9 „Zero Frequency Voltage“

The V/f curve is divided into two sections. It starts at zero frequency with a voltage defined with P8.9

„Zero Frequency Voltage“, proceeding linearly to a point defined by P8.7 „V/Hz Mid Frequency“ for

the frequency and by P8.8 „V/Hz Mid Voltage“ for the voltage, and from there to the field weakening

point (FWP). With this measure it is possible to increase the voltage in the lower range above average

to compensate the voltage drop inside the motor and to improve the torque behavior. Beside other cases this measure is used, when a drive is operated in the lower speed range stationary.

It has to be noted, that the cooling of the motor is usually realized by a fan, which is mounted on

the motor's shaft and whose cooling effect is reduced correspondingly. When a certain torque is

required in this range, it must be ensured, that the motor will not be overheated. Eventually a separately driven fan must be used.

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When setting the parameters, the motor must initially be operated unloaded with linear V/f curve. It

is presumed, that the motor data (P1.5 up to P1.9) are set already and that the general settings for

the V/f curve (see section 4) are completed.

- P8.4 „V/Hz Ratio“ = 0: Linear
- Run the motor with 2/3 of its rated speed.
- Read the motor current on the keypad or in the configuration software inControl (M4). Because of the unloaded motor the actual current corresponds approximately to the excitation current.
- Remove START signal
- Set P8.54 „Excitation Current“ to the value measured before. It is required for internal calculations.
- P8.4 „V/Hz Ratio“ = 2: Programmable
- During the following settings P1.1 „Min Frequency“ must be set to zero, even when the application requires higher values for the minimal frequency during normal operation. When the V/f settings are completed, P1.1 can be set back to the value, which is required by the

application.

- Frequency reference = 0, start variable frequency drive
- Increase the value of P8.9 “Zero Frequency Voltage”, until the current is as high as measured before.
- Stop drive
- Set P8.7 and P8.8 to the required values. The setting is application dependent. Additional to the settings here it is possible to set the motor control mode (P8.1) to “1: Speed Control” and/or to enable the “V/Hz Optimization” with P8.3. In general good results can be achieved by using the following rule of thumb:

o  $P8.8 = 1,4 - P8.9$

o  $P8.7 = P8,5 - (P8.8 : P8.6)$

Parameter Name Range Default

P8.3 V/Hz Optimization 0: Disabled

1: Enabled

0: Disabled

P8.7 V/Hz Mid Frequency 0 Hz ... P8.5 0 Hz

P8.8 V/Hz Mid Voltage P8.9 ... P8.6

P8.9 Zero Frequency Voltage 0 % ... 40 % P8.6 0 %

P8.54 Excitation current Depends on drive rating

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#### 4.1.2 Increasing energy efficiency

Objective is to reduce the losses inside the motor to increase the overall system efficiency. Because

of the voltage reduction the field of the motor is weakened, which leads to a reduction of the reac-

tive current, while the active one is increasing at the same time, but not as much as the reactive cur-

rent decreases. This leads to a decrease of the overall motor current. This principle is only applicable,

when the application doesn't require full torque in the complete speed range.

The device series DG1 has two possibilities to achieve this:

- P8.4 „V/Hz Ratio“ = 1: Squared

with this setting the voltage increases squared with the frequency, until it reaches its maximum at the FWP, see also drawing in section 4.1.1

- P8.4 „V/Hz Ratio“ = 3: Linear + Flux Optimization

In principle the V/Hz curve is linear. When the drive operates under part load conditions for a

certain time (approximately 1 minute), the voltage is automatically decreased by some Volts.

The procedure is repeated until the current is at its minimum. This leads to less losses inside the motor and to a noise reduction. In case a higher torque is required the drive returns to

its

linear V/f curve and the process starts again. This kind of energy optimization makes sense, when different torque can be required at the same speed. This principle is only applicable to drives without short term speed changes, but with constant speed for a certain time.

#### 4.2 87 Hz curve

In the majority of cases standard asynchronous motors are used up to their rated frequency. The

maximum output frequency of the variable frequency drive is 50 Hz. The power of the motor can be

increased by  $\sqrt{3}$ , by increasing the frequency from 50 Hz to 87 Hz ( $50 \text{ Hz} \cdot \sqrt{3}$ ), keeping the flux (magnetizing current) constant at the same time.

Conditions at a 400 V mains

- The motor is wound for 230/400 V (not 400/690 V)
- The windings are connected in delta.
- The variable frequency drive has a maximum output voltage of 400 V and a maximum frequency of 87 Hz.

This results in 50 Hz at 230 V.

- The variable frequency drive is selected for a current which is the rated current of the motor at 230 V.

Parameters

- P1.8 = 400 V
- P1.9 = 87 Hz (with 50 Hz on the name plate)

ATTENTION: When using a 50 Hz motor at 87 Hz, possible imbalances of the rotor can cause mechanical damages.

It is recommended to contact the motor manufacturer before using this motor at speeds above rated speed.

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Example for selection:

Motor data

- 230 / 400 V
- 3,2 / 1,9 A
- 0,75 kW
- 1410 min<sup>-1</sup>
- 50 Hz

Selection

- Device rated for 400 V, but for the current which is assigned to 230 V (here: 3,2 A) → DG1-343D3FB-C21C.

- The power of the motor results in  $0,75 \text{ kW} \cdot \sqrt{3} = 1,3 \text{ kW}$  (rated torque at  $\sqrt{3}$  times rated speed).

- The synchronous speed of the motor is  $1500 \text{ rpm} \cdot \sqrt{3} = 2598 \text{ rpm}$

- The expected speed at rated load is  $2598 \text{ rpm} - 90 \text{ rpm} = 2508 \text{ rpm}$

Remark: 90 rpm corresponds to the slip speed (1500 min <sup>-1</sup> – 1410 min <sup>-1</sup> )	
MTL5500 range	
Isolating interface units	
June 2024	
INM 5500 Rev 18	
Instruction manual	
MTL intrinsic safety solutions	
INM 5500 Rev 18ii	
DECLARATION OF CONFORMITY	
A printed version of the Declaration of Conformity has been provided separately within the original shipment of goods. However, you can find a copy of the latest version at: <a href="http://www.mtl-inst.com/certificates">http://www.mtl-inst.com/certificates</a>	
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IMPORTANT NOTE

WARNING

This manual has content describing the use and installation of safety equipment This equipment must be installed, operated and maintained only by trained competent personnel and in accordance with all appropriate international, national and local standard codes of practice and site regulations for intrinsically safe apparatus and in accordance with the instructions contained here

WARNING

This equipment must be used in accordance with the instructions in this manual otherwise the protection provided by the equipment may be impaired

ATEX

If the country of installation is governed by the Essential Health and Safety Requirements (Annex II) of the EU Directive 2014/34/EU [the ATEX Directive - safety of apparatus] then consult the ATEX safety instructions for safe use in this manual before installation.

Note: Refer to the website for multiple language safety instructions.

ELECTRICAL PARAMETERS

Refer to the certification documentation for the electrical rating of these products.

CERTIFICATION DOCUMENTATION

Our website <http://www.mtl-inst.com> contains product documentation regarding intrinsic safety certification for many locations around the world. Consult this data for information relevant to your local certifying authority.

FUNCTIONAL SAFETY

If the MTL5500 range of products are to be used in functional safety applications check that each module has been assessed for that service and refer to the Safety Manual for details.

REPAIR

MTL5500 range of products MUST NOT be repaired. Faulty or damaged products must be replaced with an equivalent certified product.

Symbols used on the product and in this manual

CAUTION -

Read the instructions

CAUTION -

Hot surface

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ATEX/UKCA/IECEx SAFETY INSTRUCTIONS

The following information is in accordance with the Essential Health and Safety Requirements (Annex II) of the EU

Directive 2014/34/EU [the ATEX Directive - safety of apparatus), and Schedule 1 of the Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 2016 (UK S.I. 2016/1107) and is

provided for those locations where the ATEX Directive or UKCA regulations are applicable.  
General

a) This equipment must only be installed, operated and maintained by competent personnel. Such personnel shall have undergone training, which included instruction on the various types of protection and installation

practices, the relevant rules and regulations, and on the general principles of area classification. Appropriate refresher training shall be given on a regular basis. [See clause 4.2 of IEC/EN 60079-17].

b) This equipment has been designed to provide protection against all the relevant additional hazards referred to in Annex II of the ATEX directive (such as clause 1.2.7) or Schedule 1 of the UK regulation (such as clause 13).

c) This equipment has been designed to meet the requirements of IEC/EN 60079-0, IEC/EN 60079-7, IEC/EN 60079-11 and IEC/EN 60079-15.

Installation

a) The installation must comply with the appropriate European, national and local regulations, which may include reference to the IEC code of practice IEC/EN 60079-14. In addition, particular industries or end users may have specific requirements relating to the safety of their installations and these requirements should also be met.

For the EU, Directive 1999/92/EC [the ATEX Directive - safety of installations} is also applicable. For the UK, the Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) is also applicable.

b) This apparatus is an associated electrical apparatus and is normally mounted in a non-hazardous [safe] area.

The equipment may be installed in a Zone 2 location providing that equipment is covered by a suitable certificate

and the relevant installation conditions are met. Refer to “Special Conditions for Safe Use – Zone 2 mounting”

below.

c) Unless already protected by design, this equipment must be protected by a suitable enclosure against:

i) mechanical and thermal stresses in excess of those noted in the certification documentation and the product

specification

ii) aggressive substances, excessive dust, moisture and other contaminants.

Read also the Special Conditions for Safe Use (below) for any additional or more specific information.

#### Special Conditions of Safe Use for Zone 2 applications

a) When used in Zone 2, the equipment must be installed in an area of Pollution Degree 2 or better, as defined in IEC 60664-1, and in an enclosure or an environment that provides a degree of protection of at least IP54 and meets the relevant material and environmental requirements of IEC/EN 60079-0, and IEC/EN 60079-7 or IEC/EN 60079-15 as appropriate.

b) The equipment must not be inserted or removed unless either:

- i) the area in which the equipment is installed is known to be non-hazardous or
- ii) the circuit to which it is connected has been de-energised.

c) The 24V supply for this equipment must be derived from a regulated power supply complying

with the requirements of European Community Directives.

d) For MTL5511, MTL5514, MTL5514D, MTL5516C, MTL5517, MTL5526 & MTL5532 only:  
Relay contacts

may switch up to 35V, 2A and 100VA.

For MTL5575: Relay contacts may switch up to 35V, 250mA.

e) For MTL5573: Maximum Input/Output parameters – see certificate

f) For MTL5553: The ambient temperature stated on the certificate refers to the temperature within the enclosure into which it must be installed in accordance with condition number 1).

It is the responsibility of the installer to ensure that there is adequate isolation between the MTL 5553

Isolator and the frame of the supplementary enclosure. The equipment must be capable of withstanding

the 500V dielectric strength test in accordance with clause 6.1 of IEC 60079-7 between the equipment

and the supplementary enclosure. This must be taken into account during installation.

The maximum values for the intrinsically safe circuits have to be taken from the IECEx Certificate of

Conformity IECEx BAS 18.0060.

g) Special Conditions will vary on individual certificates.

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#### Inspection and maintenance

a) Inspection and maintenance should be carried out in accordance with European, national and local regulations

which may refer to the standard IEC/EN 60079-17. In addition specific industries or end users may have

specific requirements which should also be met.

b) Access to the internal circuitry must not be made during operation.

#### Repair

a) This product cannot be repaired by the user and must be replaced with an equivalent certified product.

#### Marking

Each device is marked in compliance with the EU Directive and UK regulation, and CE and UKCA marked accordingly.

Example label showing markings:

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## 1 INTRODUCTION

This instruction manual describes the procedures for installing, connecting, checking and maintaining MTL5500 range of isolating interfaces and accessories. The MTL5500 products provide

a DIN-rail mounted, intrinsically safe interface to hazardous areas of a process plant.

The individual sections of this manual cover the following topics

- Section 2 describes the range
- Section 3 specifies precautions both before and during installation
- Section 4 describes mounting accessories and the power adaptor
- Section 5 discusses the DX range of enclosures
- Section 6 provides relevant technical data
- Section 7 outlines fault-finding and maintenance procedures
- Section 8 describes bench test procedure
- Section 9 provides hazardous-area application information
- Section 10 provides MTL5000 products information
- Section 11 provides safety parameter information

## 2 DESCRIPTION

MTL5500 range of isolators provide intrinsically safe (IS) communication and signal conditioning

for a wide range of hazardous-area devices. Total AC and DC isolation exists between input, output and power supply on separately powered units, and between input and output on loop-powered units. No IS earth is required. DIN-rail mounting and plug-in signal and power connectors simplify installation and maintenance. Units are powered from a 20 to 35V DC supply, or, in some cases, from the signal itself.

Our latest generation of IS interfaces utilises an innovative “One-Core” technology to ensure the highest quality and availability while maintaining maximum flexibility at lowest cost.

Incorporating advanced circuit design, a common set of components and innovative isolating

transformer construction, they achieve a significant reduction in power consumption while increasing channel packing densities. The compact, 16mm wide design reduces weight and gives exceptionally high packing density. They build on the proven success of the MTL2000, 3000, 4000 and 5000 ranges to bring the benefits of new developments in galvanic isolation without compromising the reliability of the designs from which they have evolved.

The backplane mounting MTL4500 range is designed with system vendors in mind for “project-

focussed” applications such as Distributed Control System (DCS), Emergency Shutdown Systems (ESD) and Fire and Gas monitoring (F&G).

The DIN-rail mounting MTL5500 range meets the needs of the IS interface market for “application focussed” projects, ranging from single instrument loops, through to fully equipped cabinets, across all industries where hazardous areas exist. Both new ranges have been designed for compatibility with earlier models. The MTL4500 range provides plug-replacements for earlier MTL4000 range of units, while the MTL5500 models can easily replace MTL5000 range of units. Each offer the latest in modern technology and efficiency without compromise. In addition to their use in IS circuits, specific models within the MTL4500 and MTL5500 ranges have been assessed and approved for use in Functional Safety applications. These have been verified under the certified Functional Safety Management (FSM) programme implemented by us.

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The table below lists the modules in the MTL5500 range. Refer also to the individual MTL5500 range of data sheets.

#### Digital Input Channels Function

MTL5501-SR 1 fail-safe, solid-state output + LFD alarm

MTL5510 4 switch/prox input, solid-state output

MTL5510B 4 multi-function, switch/prox input, solid-state output

MTL5511 1 switch/prox input, c/o relay output

MTL5513 2 switch/prox input, solid-state output

MTL5514/5514-T 1 switch/prox input, relay + LFD

MTL5514D 1 switch/prox input, dual relay output

MTL5516C 2 switch/prox input, relay + LFD outputs

MTL5517 2 switch/prox input, c/o relay + LFD outputs

#### Digital Output

MTL5521/5521-T 1 loop-powered solenoid driver

MTL5522 1 loop-powered solenoid driver, IIB

MTL5523 1 solenoid driver with LFD

MTL5523V 1 solenoid driver with LFD + voltage control, IIC

MTL5523VL 1 solenoid driver with LFD + voltage control, IIC

MTL5524 1 switch operated solenoid driver

MTL5525 1 switch operated solenoid driver, low power

MTL5526 2 switch operated relay

#### Pulse, Vibration and Foundation Fieldbus modules

MTL5531 1 vibration probe interface

MTL5532 1 pulse isolator, digital or analogue output

MTL5533 2 vibration probe interface

MTL5553 1 isolator/power supply for 31.25kb/s fieldbuses

#### Analogue Input

MTL5541/MTL5541-T 1 2/3 wire transmitter repeater

MTL5541A 1 transmitter repeater, passive input

MTL5541AS 1 transmitter repeater, passive input, current sink  
 MTL5541S/5541S-T 1 2/3 wire transmitter repeater, current sink  
 MTL5544 2 2/3 wire transmitter repeater  
 MTL5544A 2 transmitter repeater, passive input  
 MTL5544AS 2 transmitter repeater, passive input, current sink  
 MTL5544S 2 2/3 wire transmitter repeater, current sink  
 MTL5544D 1 2/3 wire transmitter repeater, dual output

#### Analogue Output

MTL5546 1 4-20mA smart isolating driver + LFD  
 MTL5546Y/5546Y-T 1 4-20mA smart isolating driver + oc LFD  
 MTL5549 2 4-20mA smart isolating driver + LFD  
 MTL5549Y 2 4-20mA smart isolating driver + oc LFD

#### Fire and Smoke

MTL5561 2 loop-powered for fire & smoke detectors

#### Temperature Input

MTL5573 1 temperature converter, THC or RTD  
 MTL5575 1 temperature converter, THC or RTD  
 MTL5576-RTD 2 temperature converter, RTD  
 MTL5576-THC 2 temperature converter, THC  
 MTL5581 1 mV/thermocouple isolator for low level signals  
 MTL5582/5582B 1 mV/resistance isolator to repeat RTD signals

#### General

MTL5599 1 dummy module

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### 3 INSTALLATION

#### Important

- Make sure that all installation work is carried out in accordance with all relevant local standards, codes of practice and site regulations.
- When planning the installation of MTL5500 range of isolators it is essential to make sure that intrinsically safe and non-intrinsically safe wiring is segregated, and that units are installed as required by a nationally accepted authority or as described in EN 60079-14, ISA RP 12.6 or DIN VDE-165.
- External power supply shall contain double isolation from hazardous voltages or that unit shall be supplied by Limited Power Circuit per UL/IEC 60950 or Limited Energy Circuit per UL/IEC 61010 or Class II Power Supply per NEC.
- Environmental conditions: indoor use, altitude (up to 2000m) and humidity less than 95% non condensing.
- Check that the hazardous-area equipment complies with the descriptive system document.
- If in doubt, refer to the certificate/catalogue for clarification of any aspects of intrinsic safety or contact Eaton's MTL product line or your local representative for assistance.
- Make sure the correct hazardous-area connector (field-wiring plug) is plugged into the corresponding isolator. It is recommended that the connector is identified by the same tag number as the matching isolator.

### Figure 3 1: Dimensions of MTL5500 package

Mount all MTL5500 range of isolators on low-profile (7mm) or high-profile (15mm) type T35 (top-hat) DIN-rail to EN50022, BS5584, DIN46277. This is available from Eaton, in 1 metre lengths (THR2 - DIN rail). Install isolators within the safe area unless they are enclosed in approved flameproof, pressurised or purged enclosures and ensure that the local environment is clean and free of dirt and dust. Note the ambient temperature considerations of section 3.1.4.

It is recommended that, in normal practice, the DIN rail should be earthed/grounded to ensure the safety of personnel in the event of a.c. mains (line) power being applied accidentally to the rail.

SAFEHAZ

104.8

109.8

123.6

118.8

Top of DIN rail

PWR

OPB

OP A

OPD

OPC

FLT

Optional TH5000 tag holder for individual isolator identification.

Accepts tag label 25 x 12.5  $\pm 0.5$ mm, 0.2mm thick

15.8  $\pm 0.2$

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3 1 Modules – pre-installation

3 1 1 Switch settings for operating conditions

Some modules have operating conditions, such as Line-Fault Detection (LFD), Phase Reversal,

etc., that can be established by the setting of switches on the unit. The subminiature switches

are accessible through an aperture on the side of the module (see Figure 3.2) and can be set in

the required positions with, for example, the blade of a small screwdriver.

The switch setting options are always indicated on the side label of the module, but the user may

also consult the individual module information in Section 6 of this manual for details.

Figure 3 2: Location of switches

3 1 2 Relay outputs

Reactive loads on all units with relays should be adequately suppressed. To achieve maximum

contact life on all mechanical output relays, the load should not be less than 50mW, e.g.

10mA at  $\geq$

5V DC.

### 3 1 3 Ambient temperature considerations

Ambient temperature limits for unenclosed MTL5500 range of isolators are from  $-20^{\circ}\text{C}$  to  $+60^{\circ}\text{C}$

with units close-packed and modules with the -T suffix have an extended temperature rating of

$+65^{\circ}\text{C}$ , unless otherwise specified.

### 3 2 Installing columns of isolators

On new installations, if isolators are mounted in several rows or columns, mount alternate rows or

columns so that units face in opposite directions. This allows safe- and hazardous-area wiring looms

to be shared. See Figure 3.1 for isolator dimensions.

#### 3 2 1 Mounting isolators on DIN rail

##### Figure 3 3: DIN rail mounting and removal of isolators

Clip an isolator onto the DIN rail as shown in Figure 3.3, with the blue signal plugs facing towards the hazardous-area. To remove an isolator from the rail, insert a screwdriver blade (2.5 - 5.0mm diam.) into the clip as shown. This will release the clip so that the isolator may be pivoted off the rail - there is no need to lever the clip. Allow a maximum mounting pitch of

16.2mm for each unit.

OFF position

ON position

1 2 3 4

Mounting

Removal

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### 3 2 2 Wiring up isolators

Each unit is supplied with the appropriate number and type of safe- and hazardous-area connectors

(see Figure 3.4), as dictated by the terminals used and the type of power supply.

##### Figure 3 4: Removable power and signal plugs

Note: Earth Leakage Detection requires the use of hazardous area connector type HAZ1-3, which may need to be ordered separately. See datasheet for ordering information.

Loop-powered devices do not require power connectors. Depending on the installation, it may

be easier to wire up isolators with power and signal plugs either in place or removed. Either way, allow sufficient free cable to permit plugs to be removed easily for future maintenance and/or replacement purposes. See Section 6 for instructions on wiring individual modules.

#### 3 2 2 1 Signal and power conductors

Removable signal and power plugs are fitted with screw clamp terminals. Note that the conductors should be between 14 and 24 AWG (1.6 and 0.5mm diam.) in size. Signal plugs, located on top of the modules, are mechanically keyed to fit in only one position. They are

coloured grey, for safe-area connections, and blue, for hazardous-area connections. For externally powered units, a power plug slots into the socket at terminals 13 and 14 on the safe-area side of each module. The socket is coloured black if the unit is dc powered. Power plugs are coloured grey, for plugging into the black sockets of dc powered units.

### 3 2 2 2 Making connections

- a) Trim back the insulation of conductors by 12mm.
- b) Check the terminal assignments shown in section 6 or on the side label of the unit.
- c) Insert conductors according to the terminal assignments and tighten screws.

If the wires are to be fitted with crimp ferrules, the following is a list of those recommended with

required trim lengths for each:

Plug

type

Entry Wire size

(mm<sup>2</sup>)

Metal tube

length (mm)

Trim

length

Recommended ferrules

Signal Single 0.75 12 14 Weidmuller 902591

Signal Single 1.0 12 14 Cembre PKC112

Signal Single 1.0 12 14 Phoenix Contact

AI 1-12 RD (3200674)

Signal Single 1.5 12 14 Cembre PKE1518†

Signal Single 2.5 12 14 Cembre PKE2518†

Power Twin 2x0.75 10 12 Cembre PKET7510

Power Twin 2x0.75 10 12 AMP (non-preferred) 966144-5

Power Twin 2x1.0 10 12 Phoenix Contact AI-TWIN 2X 1-10 RD

Power Single 0.75 10 12 AMP 966067-0

Power Single 1.0 10 12 Phoenix Contact AI 1-10 RD

### TABLE 3 1: Crimp Ferrule Options

† These ferrules with 18mm length metal tubes should be cut to 12mm after crimping

Note: Smaller section wire than that stated can often be successfully used if the crimping is good.

Crimp tool: Phoenix Contact Crimpfox UD6 part number 1204436

Power Plugs

Grey: dc supplies (PWR5000)

Signal Plugs

Grey: safe-area side

Blue: hazardous-area side

12mm

trim

length

with ferrule

see table below

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3 2 2 3 Finishing

Wire up individual isolators in accordance with wiring schedules. Daisy-chain power supply connections between individual power plugs or use the power bus (see section 4.1).

Segregate hazardous- and safe-area wiring into separate trunking or looms wherever possible to

avoid errors and maintain a tidy installation.

Use an MTL5599 dummy isolator to provide termination and earthing for unused cores from the

hazardous area.

#### 4 ACCESSORIES

##### 4 1 MTL5500 power bus - Installation and use

##### 4 1 1 MTL5500 range power bus

A power bus kit enables power supply terminals (13 and 14) of up to 32 installed MTL5500 range of

units to be linked to a standard 24V power supply. The bus consists of a chain of power plugs and

different lengths are available to suit various numbers of modules as follows.

Number of modules Kit ID code

(contains grey power plugs for 24V dc supply)

1 to 8 PB-8T

9 to 16 PB-16T

17 to 24 PB-24T

25 to 32 PB-32T

Table 4 1: Power bus kit options

##### 4 1 2 Installation

1. Check to make sure the bus length is correct for the number of modules involved.

2. If the number of modules is less than the maximum number the chain will support, cut off the surplus power plugs at the tail end of the chain - leaving sufficient cable to attach further

power plugs if it becomes necessary later.

3. Insert power plugs into the power terminals on the safe- area side of each module in sequence.

4. Connect the power supply source to the tail end of the chain (using the insulation displacement

connectors [Scotchlocks] provided if required).

Notes:

1. To avoid excessive voltage drop or over-current, DO NOT connect power buses in .

2. Surplus sections can be used (and, if required) connected together provided the cut ends are

safely terminated and/or connected together. Use single ferrules with a crimp tool or

insulation

displacement connectors (Scotchlocks). Suitable ferrules and connectors are provided with the kits.

Figure 4 1: Power bus wiring, joining and terminating

– +

Optional insulation

displacement

connectors

x2

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4 2 MPA5500 AC power adaptor

When only one or two MTL5500 modules are required for a particular application, it may be desirable to power the units from the AC mains supply directly, rather than use a separate DC

supply unit. The MPA5500 is an adaptor that plugs into the DC power socket on the side edge

of an MTL5500 module and clips securely onto the module housing. Its 25V DC power output is

sufficient to supply a single module and can be connected to any normal ac power source.

Figure 4 2: MPA5500 AC power adaptor

To fit the adaptor, locate the tongue of the adaptor into the top slot on the side of the MTL5500

module and press the adaptor until it fits closely to the body of the module, as shown.

Use double-insulated AC power cable with conductor parameters of 0.2–1.5mm<sup>2</sup>, or 0.25–1.5mm<sup>2</sup> if using ferrules. Strip the outer insulation by no more than 30mm, then strip the inner

conductors by 8mm. Insert the cables appropriately in the cage-clamp connectors marked 'L'

and 'N'.

The incoming AC power must have some form of power disconnection device, such as a switch

or circuit breaker; a coupler that can be disconnected without the use of a tool; or a separable

plug, without a locking device, to mate with an adjacent socket outlet.

In addition, some form of cable anchorage must be used to relieve the cable conductors from

strain, including twisting, where they connect to the adaptor, and which will also protect the insulation of the cable from abrasion.

**WARNING**

This adaptor is not suitable for use with MTL5000 range of modules.

Direction of

removal of

MPA5500

Area required

for removal of  
MPA5500

11

20 15.8

118.8

133

AC inputs

Top of DIN rail

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#### 4 3 Earth rail and tagging accessories

This section explains how to specify and assemble earth rail and tagging strip accessories for the MTL5500 range.

The accessories consist of mounting brackets, earth rails, tagging strips and associated parts. They provide facilities for earthing, terminating cable screens and tagging (identifying) the positions of individual units.

##### 4 3 1 Parts list

IMB57 Insulating mounting block (Figures 4 3, 4 4 & 4 5)

One required at each end of a tagging strip/earth rail. Suitable for low-profile (7.5mm) and high-profile (15mm) symmetrical DIN rail.

ERB57S Earth-rail bracket, straight (figure 4 3, 4 4 & 4 9)

Nickel-plated bus bar; supplied with two push fasteners, one earth-rail clamp (14mm, 35mm<sup>2</sup>) and one earth cable clamp (10mm, 16mm<sup>2</sup>).

Note: ERB57S is the preferred choice of earth-rail bracket. It is usually fitted in the upper slot on insulating mounting block IMB57.

Where the earth rail is required to be positioned at a lower height and to allow access to the IMB57

mounting screws, the straight earth-rail bracket ERB57S can be inserted in the lower slot, but only

after insulating mounting blocks IMB57 are clamped to the DIN rail. This may not be possible if, for

example, trunking is fitted. In this case, fit offset earth-rail bracket ERB570 (see figure 4.4 & 4.10) in

the upper slot: the mounting blocks can then be fitted in a restricted space with this bracket already fitted.

ERB570 Earth-rail bracket, offset (figure 4 9)

Nickel-plated bus bar; supplied with two push fasteners, one earth-rail clamp (14mm, 35mm<sup>2</sup>) and

one earth cable clamp (10mm, 16mm<sup>2</sup>).  
 ERL7 Earth rail, 1m length (figure 4 9)  
 Nickel-plated bus bar; may be cut to length.  
 TAG57 Tagging strip, 1m length (figure 4 3, 4 4 & 4 6)  
 Cut to size. Supplied with tagging strip label.  
 TGL57 Tagging strip labels, set of 10 x 0 5m (figure 4 3 & 4 4)  
 Spares replacement, for use with TAG57 tagging strip.  
 MS010 DIN rail module spacer, 10mm, pack of 5 (figure 4 7)  
 Grey spacer; Used to provide 10mm air-circulation space between modules, if necessary.  
 ETM7 Earth terminal, bag of 50 (figure 4 8)  
 For terminating cable screens and OV returns on the ERL7 earth rail. For cables  $\geq 4\text{mm}^2$ .  
 TH5000 Tag holder  
 Spares replacement.  
 Connectors (Figure 4 5)  
 Spares replacement: HAZ1-3, HAZ4-6, HAZ-CJC, PWR5000, SAF7-9, SAF10-12 (SAF1-3 and SAF4-6  
 grey connectors, also available for use in safe-area applications).  
 4 3 2 Assembly  
 4 3 2 1 Fitting earth rails  
 a) In upper position  
 Before fitting insulating mounting blocks IMB57, check that the swing nuts in the base of  
 each unit are turned back into the moulding. Locate the mounting blocks on the DIN rail in  
 the  
 chosen position and tighten the screws (see figure 4.10). Check that the swing nuts rotate  
 correctly to locate underneath the flanges of the DIN rail.  
 INM 5500 Rev 189  
 -  
 -  
 TGL57  
 TAG57  
 ERB57  
 ERB570  
 ETM7  
 Snap off extension  
 when using IMB57  
 as central support  
 10mm Earth  
 clamp  
 ERB57S  
 in upper  
 position  
 ERB57S

in lower  
position  
IMB57  
Push  
fastener  
14mm  
Earth-rail  
clamp  
ERL7  
THR2  
IMB57  
ERL7  
HAZ1-3  
HAZ4-6  
TH5000  
TAG57  
TGL57  
SAF7-9  
SAF10-12  
ERB57S  
ETM7  
PWR5000

Figure 4 3: Assembly drawing showing part numbers Figure 4 4: Mounting details

Figure 4 5: IMB57 Insulating mounting block-

Figure 4 6: TAG57 Tagging strip, 1m length

-

Figure 4 7: MS010 DIN rail module spacers

-

- -

Figure 4 8: ETM7 Earth terminals

-

-

-

-

-

- - -

Figure 4 9: Earth rails and clamps

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#### Figure 4 10: Fitting IMB57

Slide a straight earth-rail bracket ERB57S into the upper slot in each mounting block. Push two

plastic push fasteners into each bracket to locate the brackets in the mounting blocks.

Cut earth rail ERL7 to the length needed. Slide the required number of ETM7 earth terminals

(5mm or 7mm wide) onto the rail. Clamp each end of the earth rail to earth-rail brackets ERB57S

using the terminal clamps (14mm, 35mm<sup>2</sup>) supplied. Fit an earth clamp (10mm, 16mm<sup>2</sup>) to the

free end of each earth-rail bracket.

Note: For lengths of earth-rail greater than 500mm, provide additional support by installing a

third IMB57 mounting block and earth-rail bracket, mid-way between the end mounting blocks.

Snap out the perforated extension between the lugs on this mounting block if a continuous tagging strip is to be fitted (see figure 4.6).

b) In lower position, where at least 150mm clearance exists on one side, measured from the edge of the mounting block.

As for a), but slide earth-rail brackets ERB57S into the lower slots in each mounting block.

c) In lower position, where there is insufficient clearance to fit earth-rail brackets ERB57S.

As for a), but slide offset earth-rail brackets ERB57O into the upper slot in each mounting block before assembling the mounting blocks to the DIN rail. ERB57S brackets cannot be used

because they obscure the fixing screws on the mounting blocks.

#### 4 3 2 2 Fitting tagging strips

Assemble mounting blocks IMB57 to the DIN rail as above. Cut TAG57 tagging strip and label to the

length needed, and insert label so that the appropriate side is visible. Clip the strip onto the lugs on

the mounting blocks. Hinge up the strip to provide access to the tops of the isolators.

Note: If necessary, provide additional support for long lengths of tagging strip by installing an

extra IMB57 mounting block mid-way between the end mounting blocks. Snap out the perforated

extension between the lugs on this mounting block.

#### 4 3 3 Completed assemblies

Figure 4.11 illustrates a complete assembly of MTL5500 isolators using the accessories mentioned

above.

The broken-line boxes either side of the assembly represent cable trunking, and the accompanying

dimensions represent the recommended minimum spacing between the trunking and the

module

assemblies.

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--

Colour Module no Function

Yellow MTL5501-SR Digital Inputs

White MTL551x

Red MTL552x Digital Outputs

Blue MTL5531/33 Vibration

Purple MTL5532 Pulse

Blue MTL5541x

MTL5544x Analogue Inputs

Green MTL5546x

MTL5549x Analogue Outputs

Blue MTL556x Fire & Smoke

Orange MTL557x

MTL558x Temperature inputs

Grey MTL5599 Dummy isolator

Table 4 2: MTL5500 front label colour coding

Figure 4 11: MTL5500 complete assembly

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## 5 DX ENCLOSURES

Enclosures are usually selected on the basis of the number of units they will accommodate and

Table 5.1 shows the capacity of each of the enclosures. Figure 5.2 shows each type of enclosure

containing MTL5500 modules.

Table 5 1: DX range of enclosures - module capacities

Enclosure Number of MTL5500 isolators

16mm mounting pitch

DX070 4 (2\*)

DX170 10 (8\*)

(DX430) 26 (24\*) no longer available

\* Use these figures when two IMB57 mounting brackets for tagging/earth-rail accessories are included.

Note: The user should be aware that some workshop preparation may be required for the cable gland

plates before the enclosure is ready for on-site installation.

### 5 1 Environmental conditions

Environmental conditions that should be taken into account when installing DX enclosures include:-

See section

Maximum ambient temperature limits 5.1.1

Storage temperatures 5.1.2

Humidity 5.1.3

Corrosion resistance 5.1.4

Flammability 5.1.5

Impact resistance 5.1.6

Chemical resistance 5.1.7

5 1 1 Maximum outside enclosure temperature limits

Figure 5 1: Graph depicting outside enclosure temperature limits for DX enclosures used with MTL5500 isolators

The maximum outside enclosure temperature depends upon the total power dissipated by the

installed modules which, in turn, depends upon their number and type. It can also be influenced by

the Authority whose standards may need to be applied to the system, e.g. Baseefa, Factory Mutual

Research Corporation, Canadian Standards Association.

Figure 5.1 shows, in graphical form, the maximum outside enclosure temperatures (TMO) for given

levels of power dissipation.

The graph was derived from the following equation and should be used to calculate accurately the

suitability of any particular mix of modules.

$TMO = 60^{\circ}C - \Delta T$  where  $\Delta T = k1 \times P$

P = total power (watts) dissipated by modules in an enclosure

k1 = is a dissipation constant for a given enclosure and module . Select the relevant value from

Table 5.2.

(60°C is the temperature inside the enclosure)

60

40

20

10

30

50

0 10 20 30 40

Power dissipation (watts)

Max. outside enclosure  
temperature (°C)

Enclosures

DX070

DX170

DX430

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Figure 5 3: Optimum orientation for wall mounted enclosure

DX070 DX170

MTL5500 4.03 1.88

Table 5 2: Dissipation constant k1 for enclosures (°C/watt)

Orientation of the enclosures is also important - the optimum position being on a vertical surface with

the internal DIN-rail horizontal as shown in Figure 5.3. Any other position can reduce the maximum

allowable ambient temperature by up to 5°C.

Examples

Tables 5.3 and 5.4 list likely combinations of MTL5500 modules in the three enclosure types and

indicate the acceptable maximum permitted outside enclosure temperature for these based on

the graph in Figure 5.1. See the specifications included in the datasheets for the power dissipation

figures of individual MTL5500 modules.

Table 5 3: Typical mix of MTL5500 modules

Enclosure Modules installed Power dissipation of modules in watts (P)

Maximum outside

enclosure temp (TMO)°C

DX070 2 x MTL5511 + 2 x MTL5544 (2 x 0.72) + (2 x 1.4) = 4.24 42.9

DX170 5 x MTL5511 + 5 x MTL5544 (5 x 0.72) + (5 x 1.4) = 10.6 40.1

Table 5 4: Power versus maximum outside enclosure temperature

Enclosure

Number of installed

modules

k

°C/watt

Power dissipation

of modules in watts

(P)

Maximum outside

enclosure temp

(TMO) °C

DX070 4 4.03 4.0 43.9

4 4.03 6.0 35.8

DX170 10 1.88 10.0 41.2

10 1.88 15.0 31.8

5 1 2 Storage temperatures

Storage temperatures are safe within the range -40°C to +80°C.

5 1 3 Humidity limits

Safe humidity limits are within the range 5 to 95% RH.

5 1 4 Extended ambient temperature modules

Modules with the -T suffix are rated for use in an ambient temperature up to 65°C if suitably

certified.

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Figure 5 2: DX range of enclosures

150

DX070

130

113.5

153.5

70

180

163.5

203.5

Ø 5.2

184

147 (inside)

Top of DIN rail

270

8080

540

430

520

576

249

305

Ø 7.2

DX430

184

147 (inside)

Top of DIN rail

170

249

305

102 102

360

339

395

270 Ø 7.2

DX170

131 (inside)

n b

DX430

no longer

available

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#### 5 1 5 Corrosion resistance

The effect of corrosion on DX enclosures is negligible.

#### 5 1 6 Flammability rating

The flammable properties of the materials used in the construction of the enclosures are well

understood by manufacturers and ratings have been established to a number of standards.

One of

the better known standards is the Underwriter's Laboratory standard UL 94 and the ratings for the

enclosure materials are given as:

Materials UL94 rating

Polycarbonate (all lids) V2/V0

Polycarbonate with glass reinforcement (DX070 base) V1/V0

Polyester with glass reinforcement (DX170 & DX430 bases) V0

Items made from similar materials are well established as suitable for use in process I/O marshalling

areas.

#### 5 1 7 Impact resistance

The enclosure designs have been tested to an impact resistance of greater than 2 Joules which

exceeds the BS EN 61010-1 requirements of 0.5 Joules.

#### 5 1 8 Chemical resistance

The overall chemical resistance of the enclosures is limited by the resistance of the transparent

polycarbonate lid. The glass-reinforced polycarbonate/polyester (GRP) bases have a higher resistance

than plain polycarbonate. Table 5.5 lists qualitative evaluations of resistance to a variety of chemical

agents.

Table 5 5: Qualitative evaluations of resistance to various chemical agents

Chemical agents Qualitative

evaluation

of resistance

Salt water; neutral salts; acids (low concentrations); hydraulic oil Excellent

Alcohols Very good

Acids (high concentrations); alkalis (low concentrations); petrol; cooling fluids Good

Alkalis (high concentrations); solvents. Poor

#### 5 2 Mounting

##### 5 2 1 General

These instructions are concerned solely with mounting the DX enclosures. Instructions for wiring and testing individual modules within the enclosures are provided in Section 6.

Sufficient space is provided within the enclosures to accommodate tagging and earth-rail accessories but this is at the expense of a reduction in the number of modules that can be fitted.

## 5 2 2 Location and orientation

### 5 2 2 1 Location

The DX enclosures are intended for safe (non-hazardous) area use.

The enclosures are rated NEMA 4X; consequently, in N. America or Canada, assuming the modules have the required approvals, they can be used in Class 1, Division 2 (gases)

location,

but check with local requirements and ensure all cable entries also conform. In this case, an additional warning label will be required on or near the enclosure warning that the MTL5500

interfaces must not be removed unless the area is known to be non-hazardous. The enclosures

are NOT suitable for Class II or III, Division 2 hazardous locations.

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### 5 2 2 2 Orientation

As noted earlier (see section 5.1.1), for optimum temperature performance the enclosures should be mounted on a vertical surface with the internal DIN rail horizontal.

### 5 2 3 Mounting details

See Figure 5.2 for the dimensions and mounting hole distances, etc., of the three DX enclosures.

The recommended method of mounting-described here-uses the four wall-mounting lugs supplied

with each enclosure. An alternative method of mounting is by direct attachment to the mounting

surface through the corner holes.

Note: When the wall-mounting lugs are used to attach the enclosures, the overall depth of the

enclosure is increased by an additional 3.3 mm (DX070) or 7 mm (DX170 and DX430).

a) At each of the four corner fixing holes, insert one of the screws provided and use it to attach

a fixing lug to the base of the enclosure.

b) Each lug can be used in one of two positions as shown in Figure 5.2.

c) Attach the lugs to the mounting surface with suitable fasteners.

d) Diameters of fixing holes in lugs are 5.5mm (DX070) and 7.0mm (DX170 and DX430)

e) Appropriate fixing hole distances are shown in Figures 5.2.

### 5 2 4 Cable glanding

All cables into the enclosures must be glanded to IP65 standards to maintain this rating for the

enclosure as a whole. Cable glands and gland plates are not supplied. Glanding requirements vary

for each enclosure as follows:

DX070

On the DX070, 'knockout' holes are provided, in two different sizes (15.5 mm and 21 mm), on the

side faces of the base. See Table 5.7 for recommended cable glands.

## DX170

The DX170 can accommodate one gland plate on each side - see figure 5.2 for details. Table 5.6 lists

suppliers of suitable gland plate kits and Table 5.7 lists recommended glands.

Table 5 6: Recommended gland plate kits for the DX170 and DX430 enclosures.

Manufacturer/agent

Manufacturer's part number

Enclosure DX170

Hellermann Tyton TL-27/360

Sarel 21128

Table 5 7: Recommended cable glands for use with DX enclosures.

Gland

thread

size

Cable

sizes

(mm)

Gland plate

hole size

(mm)

Weidmuller part nos Sarel part nos

Gland Locknut Gland Locknut

PG9 5 to 8 15.2 951891 952216 08871 08881

PG13,5 8 to 13 20.4 951893 952218 08873 08883

Weidmuller (UK) <http://www.weidmuller.co.uk>

Sarel (UK) <http://www.sarel.co.uk>

Hellermann Tyton (UK) <http://www.hellermantyton.co.uk>

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5 3 Accessories in enclosures

Apart from mounting, there are some other installation details which should be considered before

adding the appropriate interface modules and making the necessary cabling connections.

A range of accessories is available to accompany the MTL5500 units (see section 4) and the following points should be observed.

5 3 1 Insulating mounting block (IMB57)

A pair of these can be attached to the DIN rail, at either end of the modules, to provide a mounting

for earth rails. Use of mounting blocks will reduce the space available for isolator modules.

5 3 2 Earth rails (ERL7)

Earth rail is produced in 1 metre lengths and will require cutting to length before mounting. ERL7

earth rails can be mounted either side of the modules but are typically mounted on the hazardous

side of the DIN rail.

### 5 3 3 Tagging strip (TAG57 and TGL57)

Tagging strip is produced in 1 metre lengths and will require cutting to length before mounting.

Similarly, the labels will require cutting to fit the tagging strip.

### 5 4 IS warning label

A 'Take Care' IS warning label is provided inside each enclosure. This should be attached to the inside

of the transparent lid when its orientation has been established.

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## 6 UNIT DESCRIPTIONS, SETTING-UP AND CONNECTIONS

This section describes the function (briefly), the setting-up procedure and the wiring connections

for each MTL5500 unit. For a fuller functional description and a detailed technical specification,

refer to the individual datasheets, which can be found on our website at [www.eaton.com](http://www.eaton.com) or in

the current MTL IS catalogue.

If a fault is suspected, first check that the power LED is lit (not applicable to loop-powered devices). If necessary, check that all signal and power plugs are properly inserted, that no wires

are loose and that the unit is mounted correctly. If operation is still suspect, the unit should be

replaced with a serviceable unit.

There are no replaceable parts inside MTL5500 units, so any that appear to be inoperative should

be returned to the manufacturer/supplier for repair or replacement.

### WARNING

When disconnecting units for maintenance purposes, take care to segregate hazardous and safe-area cables.

- Short circuit hazardous-area cable cores to an IS earth or insulate and secure the ends.

- Insulate and secure safe-area cables. If testing a unit 'in situ' note that the test equipment used MUST be intrinsically safe.

The rest of this section is divided into sub-sections based upon the type of module, as follows.

### 6 1 Digital Input modules

MTL5501-SR, MTL5510, MTL5510B, MTL5511, MTL5513, MTL5514, MTL5514-T, MTL5514D, MTL5516C, MTL5517

### 6 2 Digital Output modules

MTL5521, MTL5521 -T, MTL5522, MTL5523, MTL5523V, MTL5523VL, MTL5524, MTL5525, MTL5526

### 6-3 Vibration, Pulse and Foundation Fieldbus modules

MTL5531, MTL5532, MTL5533, MTL5553

### 6 4 Analogue Input modules

MTL5541, MTL5541-T, MTL5541A, MTL5541AS, MTL5541S, MTL5541S-T, MTL5544, MTL5544A, MTL5544AS, MTL5544D, MTL5544S

6 5 Analogue Output modules

MTL5546, MTL5546Y, MTL5546Y-T, MTL5549, MTL5549Y

6 5 Fire and Smoke interface modules

MTL5561

6 7 Temperature Input modules

MTL5573, MTL5575, MTL5576-RTD, MTL5576-THC, MTL5581, MTL5582, MTL5582B

6 8 General modules

MTL5599, MTL5991

6 9 PCS45/PCL45USB configurator for MTL temperature converters

Note: Any LED indicator provided on the modules will display in the following colours:

LED label LED colour

PWR (power) Green

STS (status) Yellow

LFD (line fault) Red

FLT (fault) Red

OPx (o/p status) Yellow

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6 1 Digital Input modules

The Digital Input (DI) module range offers solid state or relay output switches in a safe area that

respond to input switches located in a hazardous area. Single or multiple channel (2 or 4) options

are available, as well as Line-Fault Detection (LFD).

Modules with LFD can recognise open or short circuit conditions on the input wires going to the

field sensors, and some DI modules have the facility to reverse the effect of the input on the output

i.e. phase reversal.

These options are chosen with switches located on the edge of the module on the hazardous

area terminal side. In some applications it may be easier to set these switches before fitting the

module to the DIN-rail.

Figure 6 1: Switches to set LFD and phase reversal

6 1 1 Phase reversal

Set the PR switch ON or OFF for the appropriate channel(s).

6 1 2 Line-Fault Detection (LFD)

Where fitted, set the LF switch ON or OFF for the appropriate channel(s). Note: LFD is permanently active on the MTL5501-SR.

For all DI modules with LFD except for the MTL5501-SR; when using the LFD facility with a contact

input, resistors must be used. Fit 500Ω to 1kΩ (preferred value 680Ω) in with the switch and

20k $\Omega$

to 25k $\Omega$  (preferred value 22k $\Omega$ ) in parallel with the switch.

For modes of operation of the MTL5510 & MTL5510B that include LFD, resistors should be fitted as described above.

For MTL5501-SR use 1k4 $\Omega$  in and 10k $\Omega$  in parallel with switch contact inputs.

For hazardous-area inputs conforming to EN 60947-5-6:2001 (NAMUR), a line fault is judged by the following rules:

- Open circuit condition if hazardous-area current <50 $\mu$ A
- Line integrity (no open circuit) if hazardous-area current >250 $\mu$ A
- Short circuit condition if hazardous-area load <100 $\Omega$
- Line integrity (no short circuit) if hazardous-area load >360 $\Omega$

Note: the open circuit window (between 250 $\mu$ A and 50 $\mu$ A), and the short circuit window (between 100 $\Omega$  and 360 $\Omega$ ), is not hysteresis. All MTL5500 modules, with inputs conforming to EN 60947-5-6:2001 (NAMUR), will switch between open and complete circuit conditions within these limits.

The MTL5501-SR LFD relay de-energises when a fault condition is detected. The MTL5514 and the

MTL5517 energise the LFD relay to indicate a fault condition.

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6 1 3 MTL5501-SR - Fail-safe Switch/Proximity detector interface

Single channel, fail-safe module with line-fault detection

The MTL5501-SR enables a fail-safe switch/proximity detector located in the hazardous area to control an isolated fail-safe electronic output. It provides line-fault detection (LFD) alarm contacts and is designed for use with approved fail-safe sensors in loops that require operation

up to SIL3 according to the functional safety standard IEC 61508.

Note: For reliable, long-term operation the load on the LFD switching relay should be not less

than 50mW, e.g. 10mA at 5V DC.

Hazardous area Safe area

Vs–

Vs+

20 to 35V dc

10k $\Omega$

1k4 $\Omega$

+

–

LFD

Failsafe

output

+  
–Resistors must  
always be fitted  
for switch inputs

6  
5  
4  
3  
2  
1  
7  
8  
9  
10  
11  
12  
13  
14  
-

#### Terminal Function

1 Input –ve  
2 Input +ve  
7 Output –ve  
8 Output +ve  
10 LFD  
11 LFD  
13 Supply –ve  
14 Supply +ve

#### Figure 6 2:

Top label for  
MTL5501-SR  
Input / output characteristics  
Input value in  
sensor circuits  
Fail–safe  
output  
Operation LFD  
contacts

$2.9\text{mA} < I_s < 3.9\text{mA}$  ON Normal CLOSED  
 $I_s < 1.9\text{mA}$  &  $I_s > 5.1\text{mA}$  OFF Normal CLOSED

Is < 50µA OFF Broken line OPEN

Rs < 100Ω OFF Shorted line OPEN

Correct operation of the fail-safe output and LFD is indicated by the LEDs on the front of the unit. The yellow O/P LED is ON when the fail-safe output is energised. The red LFD LED flashes

if a line fault is detected. The fail-safe output is de-energised (OFF) if the module detects an incorrect sensor current, an open circuit or a short circuit in the sensor circuit.

Input signal sensors may be either suitable proximity sensors or switches. The proximity sensor

properties are specified in the standard EN60947-5-6:2001; however, when used with MTL5501-SR modules, additional requirements for the “low-impedance” current of  $3.4 \pm 0.5\text{mA}$  must be met. The list below shows suitable proximity sensors, all manufactured by Pepperl+Fuchs Group, Germany, and specified as usable to SIL3, according to IEC 61508:

SJ 2-SN NJ 4-12GK-SN NJ 10-30GK-SN

SJ 3,5-SN NJ 5-18GK-SN NJ 15-30GK-SN

SJ 3,5-S1N NJ 8-18GK-SN NJ 6S1+U1+N

NJ 2-11-SN NJ 6-22-SN NJ 15S+U1+N

NJ 2-11-SN-G NJ 6-22-SN-G NJ 20S+U1+N

NJ 2-12GK-SN NJ 5-30GK-S1N NJ 40-FP-SN-P1

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6 1 4 MTL5510 & MTL5510B - Switch/Proximity detector interface

4-channel, digital input and multifunction modules

These digital modules provide solid state output switches in a safe area that respond to switches

(inputs) located in a hazardous area. The way they respond - their “mode” - can be configured using a

bank of four DIL selector switches accessible through the side of the module - see Figure 6.4.

Model MTL5510 has an one output channel for each input channel and the user can reverse the

output phase if necessary to suit the application. Model MTL5510B has more varied modes that can,

for example, enable one input to affect multiple outputs or create latched outputs, etc.) The channel

output transistors - Ch1/Ch2 and Ch3/Ch4 - share a common terminal and can switch +ve or -ve

polarity signals.

Note that parallel resistors are required for switch inputs with LFD - see Section 6.1.2 for recommended values.

Hazardous area

Ch B

Vs-

Vs+

20 to 35V dc

---

+

---

---

+

---

Ch D

Ch C

Ch A

1

2

3

4

common

common

## Outputs

6

5

4

3

2

1

7

8

9

10

11

12

13

14

35

Sale area  
-

—

-

-

#### Terminal Function

- 1 Input channel A
- 2 Input channel AB common (+)
- 3 Input channel B
- 4 Input channel C
- 5 Input channel CD common (+)
- 6 Input channel D
- 7 Output channel 4
- 8 Output channel 3/4 common
- 9 Output channel 3
- 10 Output channel 2
- 11 Output channel 1/2 common
- 12 Output channel 1
- 13 Supply -ve
- 14 Supply +ve

Figure 6 3:

Top labels for

MTL5510

& MTL5510B

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Figure 6 4: DIL switches for setting mode

Tables 6.1 and 6.2 show details of the modes available and the switch settings required to obtain them.

For ease of access, it is recommended that switches are set to the required mode before installation.

Table 6.1 indicates whether the output follows the input, or the output is the reverse or antiphase of the input.

For example, in mode 0, o/p 1 = chA; so, if channel A switch is closed, then output 1 will also

be closed or short circuit. However, in mode 1, o/p 1 = chA rev., so if channel A switch is closed, then

output 1 will be the reverse, i.e. open-circuit.

Table 6.2 shows the MTL5510B modes. The logic tables and timing diagrams on the following

pages provide more detailed information on these modes.

\*Mode of operation changed August 2015

MTL5510 & MTL5510B diagnostics

If an internal fault is detected, all outputs and channel LEDs will turn off and the red Fault LED

will turn ON.

Table 6 2 - MTL5510B mode options

Switch settings MODE Function Equivalent

1 2 3 4

OFF OFF OFF OFF 0 4-ch switch input (see MTL5510 mode 0) MTL5510

ON OFF OFF OFF 1 2-ch each channel one input, two outputs

OFF ON OFF OFF 2\* Same as mode 1 with all outputs phase reversed

ON ON OFF OFF 3 2-ch, 2-pole changeover output

OFF OFF ON OFF 4 1-ch with line fault output MTL5014

ON OFF ON OFF 5 As mode 4 with changeover outputs

OFF ON ON OFF 6 1-ch with start-stop latch MTL2210B

ON ON ON OFF 7\* As mode 2 with LFD enabled

OFF OFF OFF ON 8 4-ch switch input, see MTL5510 mode 8 MTL5510

ON OFF OFF ON 9 2-ch with line fault output MTL5017

OFF ON OFF ON 10 As mode 9 with LFD changeover

ON ON OFF ON 11 As mode 10 with channel phase reversed

OFF OFF ON ON 12 3-ch with normally-open LFD output

ON OFF ON ON 13 3-ch with normally-closed LFD output

OFF ON ON ON 14 2-ch monostable, pulse stretcher

ON ON ON ON 15 4-ch switch input, see MTL5510 mode 15 MTL5510

Table 6 1 - MTL5510 mode options

Switch setting MODE o/p 1 o/p 2 o/p 3 o/p 4 i/p type

1 2 3 4

OFF OFF OFF OFF 0 chA chB chC chD

switch /

prox.

detector

ON OFF OFF OFF 1 chA rev. chB chC chD

OFF ON OFF OFF 2 chA chB rev. chC chD

ON ON OFF OFF 3 chA chB chC rev. chD

OFF OFF ON OFF 4 chA chB chC chD rev.

ON OFF ON OFF 5 chA rev. chB chC rev. chD

OFF ON ON OFF 6 chA chB rev. chC chD rev.  
 ON ON ON OFF 7 chA rev. chB rev. chC rev. chD rev.  
 OFF OFF OFF ON 8 chA chB chC chD  
 Switch/  
 prox.  
 detector  
 + LFD  
 ON OFF OFF ON 9 chA rev. chB chC chD  
 OFF ON OFF ON 10 chA chB rev. chC chD  
 ON ON OFF ON 11 chA chB chC rev. chD  
 OFF OFF ON ON 12 chA chB chC chD rev.  
 ON OFF ON ON 13 chA rev. chB chC rev. chD  
 OFF ON ON ON 14 chA chB rev. chC chD rev.  
 ON ON ON ON 15 chA rev. chB rev. chC rev. chD rev.  
 --

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MTL5510B modes

The following logic and timing diagrams are provided to assist the user in understanding the behaviour of the MTL5510B module when a specific mode is chosen.

The open switch ( ) and closed switch ( ) symbols are used to represent both the input conditions of Ch A, Ch B, Ch C or Ch

D and then the output conditions of o/p 1, 2, 3 or 4. Note that in certain modes a Line Fault can cause an override of the output.

How to use these mode tables - examples

The logic tables for Mode 1 represent Ch A controlling outputs 1 & 3, while Ch C controls outputs 2 & 4.

Output 1 & 3 are shown following input Ch A (open or closed) while Outputs 2 & 4 follow input Ch C.

Mode 2 however shows o/p 1, 2, 3 and 4 being in antiphase to their inputs.

Mode 9 operates with both outputs for each channel being in antiphase to their inputs.

Mode 3: 2 ch, 2 pole c/o output

i/p - Ch A i/p - Ch C

o/p 1 --

o/p 2 --

-- o/p 3

-- o/p 4

i/p - Ch A

No

fault Line

fault No  
 fault Line  
 fault  
 o/p 1  
 Mode 4: 1 ch with line fault output  
 No  
 fault  
 Line  
 fault  
 No  
 fault  
 Line  
 fault  
 o/p 3  
 i/p - Ch A  
 No  
 fault Line  
 fault No  
 fault Line  
 fault  
 o/p 1  
 o/p 2  
 Mode 5: As mode 4 with c/o outputs  
 No  
 fault Line  
 fault No  
 fault Line  
 fault  
 LFD o/p 3  
 LFD o/p 4  
 A  
 Start  
 B  
 Stop  
 i/p Ch A  
 i/p Ch B  
 o/p 2&4  
 o/p 1&3  
 BRes  
 et  
 \*  
 \* i/p Ch A can be open or closed when i/p Ch B opens to stop latch  
 Latching  
 Ch C closed

\* i/p Ch A can be open or closed when i/p Ch B opens to stop latch

o/p 2&4

o/p 1&3

(enable)

i/p Ch A

i/p Ch B

Non-latching

Ch C open

Mode 1: 2 ch, each ch 1 input 2 outputs

i/p - Ch A i/p - Ch C

o/p 1 --

-- o/p 2

o/p 3 --

-- o/p 4

Mode 2: As mode 1 with all outputs phase reversed

i/p - Ch A i/p - Ch C

o/p 1 --

-- o/p 2

o/p 3 --

-- o/p 4

Mode 7: As mode 2 with LFD enabled

i/p Ch C Non-latching

i/p Ch B Enable

i/p Ch A

o/p 1

o/p 2

o/p 3

o/p 4

Mode 6: 1 ch with start/stop latch

OR

i/p Ch C Latching

i/p Ch A

i/p Ch B No effect

o/p 1

o/p 2

o/p 3

o/p 4

Start Reset

Stop

i/p - Ch A

No

fault Line

fault No

fault Line

fault  
 o/p 1  
 o/p 3  
 i/p - Ch C  
 o/p 2  
 o/p 4  
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 MTL5510B modes - continued  
 Mode 14  
 This mode provides a two channel pulse stretcher for in-  
 puts A and C. Outputs 1 and 2 respond to Ch A, while 3 and  
 4 respond to Ch C.  
 Input B (or D) being open or closed affects the input  
 i/p A (C)  
 o/p 2 (4)  
 o/p 1 (3)  
 Initiate  
 1sec (min.)  
 End i/p B (D)  
 1sec (min.)  
 i/p A (C)  
 o/p 2 (4)  
 o/p 1 (3)  
 i/p B (D) Initiate End  
 transition and the output polarity as shown in the timing  
 diagrams below.  
 When triggered by A (or C) the outputs hold the change  
 of state for a minimum of 1 second or as long as the input  
 (A or C) remains in the same triggered state.  
 Input Ch B (or D) closed Input Ch B (or D) open  
 Mode 9: 2 ch with line fault output  
 i/p - Ch A  
 No  
 fault Line  
 fault No  
 fault Line  
 fault  
 o/p 1  
 No  
 fault Line  
 fault No  
 fault Line  
 fault  
 LFD o/p 3

i/p - Ch C  
No  
fault Line  
fault No  
fault Line  
fault  
o/p 2  
No  
fault  
Line  
fault  
No  
fault  
Line  
fault  
LFD o/p 3  
LFD o/p 4  
Mode 10: As mode 9 with line fault c/o  
i/p - Ch A  
No  
fault Line  
fault No  
fault Line  
fault  
o/p 1  
i/p - Ch C  
No  
fault  
Line  
fault  
No  
fault  
Line  
fault  
o/p 2  
No  
fault Line  
fault No  
fault Line  
fault  
LFD o/p 3  
LFD o/p 4  
Mode 11: As mode 10 with ch phase reversed  
i/p - Ch A

No	
fault	Line
fault	No
fault	Line
fault	
o/p 1	
i/p - Ch C	
No	
fault	
Line	
fault	
No	
fault	
Line	
fault	
o/p 2	
No	
fault	
Line	
fault	
No	
fault	
Line	
fault	
LFD o/p 4	
Mode 12: 3 ch with common LFD output	
i/p - Ch A	
No	
fault	
Line	
fault	
No	
fault	
Line	
fault	
o/p 1	
i/p - Ch B	
No	
fault	
Line	
fault	
No	
fault	
Line	

fault  
 o/p 2  
 i/p - Ch C  
 No  
 fault Line  
 fault No  
 fault Line  
 fault  
 o/p 3  
 Mode 13: As mode 12 but with LFD o/p 4 reversed  
 No  
 fault  
 Line  
 fault  
 No  
 fault  
 Line  
 fault  
 LFD o/p 4  
 INM 5500 Rev 1825  
 6 1 5 MTL5511 - Switch/Proximity detector interface  
 Single channel, with line-fault detection  
 The MTL5511 contains a changeover relay, which enables a safe-area load to be controlled by a switch or proximity detector located in a hazardous-area. When selected, the line-fault detect (LFD) facility detects open or short circuit conditions in the field wiring and also indicates this on the top of the module. Line-Fault Detect and Phase Reversal for the channel are selected by DIL switches on the side of the module and output is provided by the changeover relay contacts.  
 See page 19 for LFD and PR switch details. Channel 1 only switch settings apply.  
 For switch sensor inputs, with LFD selected, make sure resistors (22k $\Omega$  and 680 $\Omega$ ) are fitted.  
 Note: For reliable, long-term operation the load on the output switching relay should be not less than 50mW, e.g. 10mA at 5V DC.  
 Vs-  
 Vs+  
 20 to 35V dc  
 22k $\Omega$   
 680 $\Omega$   
 +  
 -

## Output

Switch-type sensors

require resistors

if LFD is selected

6

5

4

3

2

1

7

8

9

10

11

12

13

14

Hazardous area Safe area

-

## Terminal Function

1 Input -ve

2 Input +ve

10 Output normally-closed contact

11 Output common

12 Output normally-open contact

13 Supply -ve

14 Supply +ve

Figure 6 5:

Top label

for MTL5511

INM 5500 Rev 1826

6 1 6 MTL5513 - Switch/Proximity detector interface

Two-channel, with line-fault detection and phase reversal

The MTL5513 enables two solid-state outputs in the safe area to be controlled by two switches

or proximity detectors located in the hazardous area. The Ch1/Ch2 output transistors share a common terminal and can switch +ve or -ve polarity signals. Line-Fault Detect and Phase Reversal for the channel are selected by DIL switches on the side of the module. LFD indication is provided on the top of the module.

See page 19 for LFD and PR switch details. Channel 1 & 2 switch settings apply.

For switch sensor inputs, with LFD selected, make sure resistors (22k $\Omega$  and 680 $\Omega$ ) are fitted.

Vs–

Vs+

20 to 35V dc

Ch 1

Ch 2

Outputs

+

–

22k $\Omega$

680 $\Omega$

+

–

Switch-type sensors

require resistors

if LFD is selected

22k $\Omega$

680 $\Omega$

6

5

4

3

2

1

7

8

9

10

11

12

13

14

Hazardous area Safe area

-

Terminal Function

1 Input –ve (Ch 1)

2 Input +ve (Ch 1)

4 Input –ve (Ch 2)  
5 Input +ve (Ch 2)  
10 Output (Ch 2)  
11 Output (Ch 1/Ch 2)  
12 Output (Ch 1)  
13 Supply –ve  
14 Supply +ve

Figure 6 6:

Top label

for MTL5513

INM 5500 Rev 1827

6 1 7 MTL5514(-T)/MTL5514D - Switch/Proximity detector interface

Single channel, with line-fault detection and phase reversal

The MTL5514(-T) enables a safe-area load to be controlled, through a relay, by a proximity detector or switch located in a hazardous area. Line faults are signalled through a separate relay

and indicated on the top of the module. The MTL5514D provides signal duplication, enabling

two safe-area loads to be controlled by a single device in a hazardous area. Both relay outputs

reflect the input signal instead of one showing the line fault condition as in the MTL5514.

Line-

Fault Detect and Phase Reversal for the channel are selected by DIL switches on the side of the module and output is provided by changeover relay contacts.

See page 19 for LFD and PR switch details. Channel 1 only switch settings apply.

For switch sensor inputs, with LFD selected, make sure resistors (22k $\Omega$  and 680 $\Omega$ ) are fitted.

Note: For reliable, long-term operation the load on the output switching relays should be not less

than 50mW, e.g. 10mA at 5V DC.

-

Terminal Function

MTL5514 (-T) MTL5514D

1 Input –ve (Ch 1)  
2 Input +ve (Ch 1)  
7 LFD Output contact N.C. Output 2 contact N.C.  
8 LFD Output common Output 2 common  
9 LFD Output contact N.O. Output 2 contact N.O.  
10 Output contact N.C. Output 1 contact N.C.  
11 Output common Output 1 common  
12 Output contact N.O. Output 1 contact N.O.  
13 Supply –ve

14 Supply +ve

Figure 6 7:

Top label

for MTL5514 (-T)

& MTL5514D

Hazardous area Safe area

Vs—

Vs+

20 to 35V dc

22kΩ

680Ω

+

—

O/P

LFD

Switch-type sensors

require resistors

if LFD is selected

6

5

4

3

2

1

7

8

9

10

11

12

13

14

LFD

O/P1

O/P2

7

8

9

10

11

12

INM 5500 Rev 1828

6 1 8 MTL5516C - Switch/Proximity detector interface

Two channel, with line-fault detection

The MTL5516C contains two changeover relays, which enable two safe-area loads to be controlled by switches or proximity detectors located in a hazardous-area. When selected, the line-fault detect (LFD) facility detects open or short circuit conditions in the field wiring and also indicates this on the top of the module. Line-Fault Detect and Phase Reversal for the channel are selected by DIL switches on the side of the module and output is provided by the changeover relay contacts.

See page 19 for LFD and PR switch details. Channel 1 & 2 switch settings apply.

For switch sensor inputs, with LFD selected, make sure resistors (22k $\Omega$  and 680 $\Omega$ ) are fitted.

Note: For reliable, long-term operation the load on the output switching relays should be not less

than 50mW, e.g. 10mA at 5V DC.

Vs–

Vs+

20 to 35V dc

+

–

+

– Ch 2

Ch 1

22k $\Omega$

680 $\Omega$

22k $\Omega$

680 $\Omega$

Switch-type sensors

require resistors

if LFD is selected

6

5

4

3

2

1

7

8

9

10

11

12

13

14

Hazardous area Safe area

-

#### Terminal Function

- 1 Input –ve (Ch 1)
- 2 Input +ve (Ch 1)
- 4 Input –ve (Ch 2)
- 5 Input +ve (Ch 2)
- 7 Normally-closed contact (Ch 2)
- 8 Common (Ch 2)
- 9 Normally-open contact (Ch 2)
- 10 Normally-closed contact (Ch 1)
- 11 Common (Ch 1)
- 12 Normally-open contact (Ch 1)
- 13 Supply –ve
- 14 Supply +ve

Figure 6 8:

Top label

for MTL5516C

INM 5500 Rev 1829

6 1 9 MTL5517 - Switch/Proximity detector interface

Two channel, with line-fault detection and phase reversal

The MTL5517 enables two safe-area loads to be controlled, through a relay, by switches or proximity detectors located in a hazardous-area. When selected, the line-fault detect (LFD) is

signalled through a separate relay and indicated on the top of the module. Line-Fault Detect and Phase Reversal for the channel are selected by DIL switches on the side of the module and output is provided by the relay contacts.

See page 19 for LFD and PR switch details. Channel 1 & 2 switch settings apply.

For switch sensor inputs, with LFD selected, make sure resistors (22k $\Omega$  and 680 $\Omega$ ) are fitted.

Note: For reliable, long-term operation the load on the output switching relays should be not less

than 50mW, e.g. 10mA at 5V DC.

Vs–

Vs+

20 to 35V dc

LFD

+

–

+

—  
 Switch-type sensors  
 require resistors  
 if LFD is selected  
 Ch 2  
 Ch 1  
 LFD  
 22k $\Omega$   
 680 $\Omega$   
 22k $\Omega$   
 680 $\Omega$   
 6  
 5  
 4  
 3  
 2  
 1  
 7  
 8  
 9  
 10  
 11  
 12  
 13  
 14  
 LFD  
 Hazardous area Safe area  
 -

Terminal Function  
 1 Input –ve (Ch 1)  
 2 Input +ve (Ch 1)  
 4 Input –ve (Ch 2)  
 5 Input +ve (Ch 2)  
 7 Line-fault detection  
 8 Output (Ch 2)  
 9 Output (Ch 2)  
 10 Line-fault detection

11 Output (Ch 1)

12 Output (Ch 1)

13 Supply –ve

14 Supply +ve

Figure 6 9:

Top label

for MTL5517

INM 5500 Rev 1830

6 2 Digital Output modules

The single channel Digital Output (DO) module range enables on/off devices in a hazardous area

to be controlled from the safe area. Some units are loop powered while others enable solid-state

switching by providing independent power supplies.

6 2 1 MTL5521(-T) - Solenoid Alarm driver

Single channel, loop powered, IIC

The MTL5521(-T) is a loop-powered module that enables a device located in the hazardous area

(IIC gas group) to be controlled from the safe area. The MTL5521(-T) can drive a certified intrinsically safe low-power load, as well as non-energy-storing simple apparatus such as an LED.

6

5

4

3

2

1

7

8

9

10

11

12

13

14

Solenoid, alarm

or other IS device

20 – 35Vdc

–

+

+

–

To earth leakage

detector \*

Hazardous area Safe area

-

-

Terminal Function

1 Output –ve

2 Output +ve

11 Supply –ve

12 Supply +ve

Figure 6 10:

Top label

for MTL5521(-T)

INM 5500 Rev 1831

6 2 2 MTL5522 - Solenoid Alarm driver

Single channel, loop powered, IIB

The MTL5522 is a loop-powered module which enables a device located in the hazardous area

(IIB gas group) to be controlled from the safe area. The MTL5522 can drive a certified intrinsically

safe, low-power load as well as non-energy-storing simple apparatus such as an LED.

6

5

4

3

2

1

7

8

9

10

11

12

13

14

Solenoid, alarm

or other IS device

20 – 35Vdc

—

+

+

—

Hazardous area Safe area

-

-

Terminal Function

1 Output –ve

2 Output +ve

11 Supply –ve

12 Supply +ve

Figure 6 11:

Top label

for MTL5522

INM 5500 Rev 1832

Hazardous area Safe area

6 2 3 MTL5523 - Solenoid Alarm driver

Single channel, with line-fault detection, IIC

The MTL5523 interface controls an on/off device in a hazardous area using a volt-free contact

or logic signal in the safe area, and is suitable for driving loads such as solenoids. Line-Fault Detection (LFD) operates independently of the output state and is signalled by a safe-area, solid-state switch output which, when a field line is open or short-circuited, becomes de-energised. Earth-fault detection can be provided by connecting an earth leakage detector to terminal 3.

6

5

4

3

2

1

7

8

9

10

11

12

13

14

Solenoid, alarm

or other IS device

+

–

Vs–

Vs+

20 to 35V dc

+

–

LFD

+

‡

‡ link to reverse output phase  
Control  
-

#### Terminal Function

- 1 Output –ve
- 2 Output +ve
- 7 Line fault signal -ve
- 8 Phase reversal link
- 9 Phase reversal link
- 10 Line fault signal +ve
- 11 Control –ve
- 12 Control +ve
- 13 Supply –ve
- 14 Supply +ve

Figure 6 12:

Top label

for MTL5523

INM 5500 Rev 1833

6 2 4 MTL5523V/MTL5523VL - Solenoid Alarm driver

Single channel, voltage controlled with line-fault detection, IIC

With the MTL5523V or MTL5523VL interface, an on/off device in a hazardous area can be controlled by a voltage signal in the safe area. It is suitable for driving loads such as solenoids.

Line fault detection (LFD), which operates irrespective of the output state, is signalled by a safe-

area, solid-state switch which energises if a field line is open or short-circuited.

The VL version has a lower current capability to suit alternative load requirements - see datasheet.

Hazardous area Safe area

#### Terminal Function

- 1 Output –ve
- 2 Output +ve
- 7, 8, 9 Line fault signal –ve
- 10 Line fault signal +ve
- 11 Control –ve
- 12 Control +ve
- 13 Supply –ve
- 14 Supply +ve

6

5

4

3

2

1

7

8

9

10

11

12

13

14

Solenoid, alarm  
or other IS device

+

—

Vs—

Vs+

20 to 35V dc

+

—

LFD

+

ControlV

PWR

STS

MTL5523V

PWR

STS

MTL5523VL

Figure 6 13:

Top labels

for MTL5523V

& MTL5523VL

INM 5500 Rev 1834

Hazardous area Safe area

6 2 5 MTL5524 - Solenoid Alarm driver

Single channel, powered, logic drive with phase reversal

The MTL5524 enables an on/off device in a hazardous area to be controlled by a volt-free contact or logic signal in the safe area. It can drive loads such as solenoids, alarms, LEDs and other low power devices that are certified as intrinsically safe or are classified as non-energy-storing simple apparatus.

6

5

4  
 3  
 2  
 1  
 7  
 8  
 9  
 10  
 11  
 12  
 13  
 14  
 Solenoid, alarm  
 or other IS device  
 +  
 –  
 Vs–  
 Vs+  
 20 to 35V dc  
 +  
 –  
 Control  
 ‡  
 ‡ use link to reverse phase  
 -

Terminal Function  
 1 Output –ve  
 2 Output +ve  
 8 Phase reversal link  
 9 Phase reversal link  
 11 Control –ve  
 12 Control +ve  
 13 Supply –ve  
 14 Supply +ve

Figure 6 14:

Top label

for MTL5524

INM 5500 Rev 1835

6 2 6 MTL5525 - Solenoid Alarm driver

Single channel, low current, loop powered, IIC

The MTL5525 enables an on/off device in a hazardous area (IIC gas group) to be controlled by a switch or voltage change in the safe area. It can drive loads such as solenoids, alarms,

LEDs and other low power devices that are certified as intrinsically safe or are classified as non-energy-storing simple apparatus. Similar in function to the MTL5521, this module provides

lower power output and corresponding reduced safety description.

6

5

4

3

2

1

7

8

9

10

11

12

13

14

Solenoid, alarm  
or other IS device

20 – 35Vdc

–

+

+

–

Hazardous area Safe area

-

-

Terminal Function

1 Output –ve

2 Output +ve

11 Supply –ve

12 Supply +ve

Figure 6 15:

Top label

for MTL5525

INM 5500 Rev 1836

6 2 7 MTL5526 - Switch Operated Relay

Two channel, output

The MTL5526 enables two separate IS circuits in a hazardous area to be relay-contact controlled

by two on-off switches or logic signals in a safe area. Applications include the calibration of strain-gauge bridges; changing the polarity (and thereby the tone) of an IS sounder; the testing

of IS fire alarms; and the transfer of safe-area signals into an annunciator with IS input terminals not segregated from each other. The output-relay contacts are certified as non-energy-storing apparatus, and can be connected to any IS circuit without further certification, provided that separate IS circuits are such that they would remain safe if connected together.

1

2

3

4

5

6

7

8

9

10

11

12

13

14

IS relay

IS relay

1

Vs-

Vs+

20 to 35V dc

+

-

2

+

-

Control

20 to

35V dc

+

-

+

-

Loop

powered

Contact

inputs

All contacts shown

in normal position  
(relays de-energised)

1

2

Sw4

Hazardous area Safe area

-

#### Terminal Function

1 IS relay output 1 (normally open)

2 IS relay output 1 (normally closed)

3 IS relay output 1 (common)

4 IS relay output 2 (common)

5 IS relay output 2 (normally closed)

6 IS relay output 2 (normally open)

8 Relay 1 control +ve

9 Relay 1 control -ve

10 Relay 2 control +ve

11 Relay 2 control -ve

13 Supply -ve

14 Supply +ve

OFF position

ON position

1 2 3 4

Table 6 3:

Switch settings

for modes

Mode Function SW1 SW2 SW3 SW4

Contact/Logic

Input

2 ch Off On On On

1in2out On On On On

Loop Powered 2 ch Off Off Off Off

Figure 6 16:

Top label

for MTL5526

INM 5500 Rev 1837

6 3 Pulse, Vibration and Foundation Fieldbus modules

Single and dual channel modules are available to transfer vibration probe signals from a hazardous area to a safe one. Similarly, pulses from a switch, proximity detector, current

pulse

transmitter or voltage pulse transmitter, located in the hazardous area, can be safely transferred

to the safe area.

### 6 3 1 MTL5531 - Vibration Transducer Interface

Single channel

The MTL5531 repeats a signal from a vibration sensor in a hazardous area, providing an output

for a monitoring system in the safe area. The interface is compatible with 3-wire, eddy-current

probes and accelerometers or 2-wire current sensors, and selection of the mode is made with

a switch located on the side of the module

Hazardous area Safe area

6

5

4

3

2

1

7

8

9

10

11

12

13

14

COM

SIG

V–

Vibration

transducer

Vibration

transducer

Vs–

Vs+

20 to 35V dc

–ve

0V

Monitor

3-

wire

2-

wire 2

1

3

Terminal Function

1 Transducer power V–

2 Signal

3 Common

11 Signal output –ve

12 Signal output 0V

13 Supply –ve

14 Supply +ve

-

OFF position

ON position

2-/3-wire

2-/3-wire transducer setting switch

Mode SW

2-wire (3 3mA)\* OFF

3-wire (20mA) ON

\* Note: When using 2-wire sensors,  
ensure that terminals 1 and 2 are linked  
as shown in the wiring diagram above.

**WARNING** - Revision status 05 and below\*

To enable optimum heat dissipation the recommended orientation for mounting is  
with the module vertical, i e with the vents in the case at the top and bottom This  
enables air to flow through the module

In any other orientation, i e with the module horizontal, then the maximum ambient  
temperature is limited to:

- Close packed = 45°C
- Minimum of 10mm spacing = 55°C

Eaton produce the MS010 DIN rail module spacer for this purpose

(packs of 5 - see Section 4 3)

\*Revision status is the 2 digits after the +++ in the barcode number

Figure 6 17:

Top label

for MTL5531

INM 5500 Rev 1838

6 3 2 MTL5532 - Pulse Isolator

Pulse & 4/20mA current outputs

The MTL5532 isolates pulses from a switch, proximity detector, current pulse transmitter  
or voltage pulse transmitter located in a hazardous area. It is ideal for applications involving  
high pulse rates and fast response times, by repeating the pulses into the safe area, and the  
transistors used on the pulse output will switch +ve or –ve polarity signals.

It may be used immediately in simple or legacy mode, or it may be software configured for more

specific applications - see next page for either option. With configuration, an analogue output

proportional to frequency is available, together with a relay output, which may act as an alarm.

Note: For reliable, long-term operation the load on the output switching relay should not be less

than 50mW, e.g.10mA at 5VDC.

Hazardous area Safe area

6

5

4

3

2

1

7

8

9

10

11

12

13

14

Vs-

Vs+

20 to 35V dc

3-wire

current

pulse

4/20

mA

-

+

3-wire

voltage

pulse

5

4

1

2-wire

current

pulse

Voltage

pulse  
 Current  
 pulse  
 5  
 1  
 Inhibit  
 Load  
 Alarm  
 4/20mA  
 Configuration  
 socket  
 —  
 +  
 1  
 4  
 +  
 Pulse  
 —  
 +  
 Pulse  
 4  
 3  
 V  
 4/20  
 mA  
 3  
 1  
 3  
 4/20  
 mA  
 Terminal Function  
 1 Common input –ve  
 2 Switch/proximity input +ve  
 3 Current pulse input +ve  
 4 Transmitter supply +ve  
 5 Voltage pulse input +ve  
 6 Inhibit input +ve  
 7 Alarm output  
 8 Current output –ve  
 9 Current output +ve  
 10 Alarm output  
 11 Pulse output –ve  
 12 Pulse output +ve  
 13 Supply –ve

14 Supply +ve

-

Vsp SW1 SW2

3V ON ON

6V ON OFF

12V OFF OFF

OFF position

ON position

1 2 3 4

SW1 SW2 SW3 SW4

Vsp Vsp LFD Mode

LFD SW3

OFF OFF

ON ON

Switches located on the edge of the module define the mode of operation.

Figure 6 18:

Top label

for MTL5532

INM 5500 Rev 1839

Switch input operation

If switch contacts are used for this Pulse Input (terminals 1 & 2), then and parallel resistors must be fitted - see Section 6.1.2 for recommended values.

Simple or Legacy mode - SW4 - OFF

If simple "pulse-in/pulse-out" operation is required or, if a replacement for the earlier MTL5032

pulse isolator is required, then SW4 should be set to OFF. The input switching point voltage (Vsp) thresholds can then be defined by Switches 1 & 2, and the LFD operation can be set with

Switch 3. When Switch 3 is ON, the Alarm output (terminals 11 & 12) become active.

Configurable mode - SW4 - ON

In this mode, analogue, alarm and pulse outputs are available but the module must be software

configured to define its operating mode. In this mode, software controls the LFD function and

Switch 3 has no effect. Switches 1 & 2 continue to define the switching point threshold (Vsp).

Configuration requires a personal computer, a PCL45USB interface and PCS45 software. See Section 6.9 for details of the configurator.

Alarm inhibiting

The Inhibit input is provided to inhibit alarm output operation. This facility is useful, for

example,  
during power-up, when pulse rates are below the alarm threshold. When normal  
operational  
values are established the inhibit can be disabled. Such a facility is sometimes referred to  
as a start-up delay. Inhibit is enabled by connecting a switch or proximity detector between  
terminals 6 and 3. If switch contacts are used for this input, then and parallel resistors must  
be  
fitted - see Section 6.1.2 for recommended values.

#### LED indicators

Use the following LED information to understand the module status.

#### LED Description

##### PWR

Power (green) ON - Power OK OFF - No power or insufficient voltage

##### O/P

##### Output (yellow)

The LED will follow the pulse output state. If the output is pulsing then  
the LED brightness will pulse. If the pulsing is rapid or very short, the LED  
may dim if it is unable to respond to such changes.

If the output is high, the LED will be ON.

##### STS

##### Status

##### (red - flashing)

In legacy mode a line fault will cause the LED to turn ON.

In mC mode, the LED is programmable to display a line fault or an Alarm  
trip operation. In the event, it will also indicate a mC fault condition.

#### INM 5500 Rev 1840

#### 6 3 3 MTL5533 - Vibration Transducer Interface

(Reference use only: Terminated product, use 2 x MTL5531)

##### Two channel

The MTL5533 repeats signals from vibration sensors in a hazardous area, providing outputs  
for monitoring systems in the safe area. The interface is compatible with 3-wire eddy-  
current

probes and accelerometers or 2-wire current sensors, and selection of the mode for each  
channel is made with the switches on the side of the module.

##### Hazardous area Safe area

##### Vibration

##### transducer

##### Vibration

##### transducer

##### Vibration

##### transducer

##### Vibration

##### transducer

##### COM

SIG  
V—  
COM  
SIG  
V—  
Vs—  
Vs+  
20 to 35V dc  
—ve  
0V  
Monitor  
3-  
wire  
2  
1  
3-  
wire  
2-  
wire  
5  
4  
2-  
wire  
Monitor  
—ve  
0V  
3  
6  
Ch 1  
Ch 2  
Ch 1  
Ch 2  
6  
5  
4  
3  
2  
1  
7  
8  
9  
10  
11  
12

13

14

Terminal Function

1 Transducer power V– (Ch1)

2 Signal (Ch1)

3 Common (Ch1)

4 Transducer power V– (Ch2)

5 Signal (Ch2)

6 Common (Ch2)

8 Signal output –ve (Ch2)

9 Signal output 0V (Ch2)

11 Signal output –ve (Ch1)

12 Signal output 0V (Ch1)

13 Supply –ve

14 Supply +ve

-

OFF position

ON position

Ch 1 Ch 2

2-/3-wire transducer setting switches

Mode SW

2-wire (3 3mA) OFF

3-wire (20mA) ON

\* Note: When using 2-wire sensors, ensure that terminals 1 & 2 and 4 & 5 have wiring links as shown in the wiring diagram above.

**WARNING!**

To enable adequate heat dissipation from the MTL5533 modules, they must be installed on the DIN rail with a 10mm space between adjacent units Eaton produce the MS010 DIN rail module spacer for this purpose (packs of 5 - see Section 4 3), and these then enable operation in ambient temperatures of up to 50°C in vertical or horizontal orientation

Figure 6 19:

Top label

for MTL5533

INM 5500 Rev 1841

6 3 4 MTL MTL5553 isolator/power supply for 31 25kbit/s fieldbuses

The MTL5553 has been specifically developed to extend 31.25kbit/s (H1) fieldbus networks into

hazardous areas. It provides power, communication and IS isolation to devices powered through

the signal conductors. The MTL5553 complies with the requirements of Fieldbus Foundation™

specified power supply Type 133 (IS power supply). To comply with fieldbus standards, each bus must be terminated at both ends. MTL's FBT1-IS or FCS-MBT fieldbus terminators (see section 6.33?) can be supplied for this purpose or, for installations in which the safe-area bus length is small, the MTL5553 includes an internal safe-area terminator which is enabled by making a link between terminals 7&8 on the top of the unit. For network and termination criteria, check applicable fieldbus standards and specification IEC 61158-2, ISA-S50.02 for 31.25kbit/s fieldbus systems, Foundation™ Fieldbus 31.25kbit/s Physical LayerProfile Specification FF-816 and MTL's Application Brief AB002.)

Hazardous area Safe area

20-35V dc

Vs+

Vs-

+ve

-ve

+ve

-ve

Host

(31.25kbit/s)

Terminator

1

2

4

5

+ve

-ve

+ve

-ve

Field

(31.25kbit/s)

6

3

2.6W Max

8

9

T

14

13

11

10

7

12

Link 7- 8 for Terminator

Terminal Function

1 Hazardous-area fieldbus device(s) connection –ve

2 Hazardous-area fieldbus device(s) connection +ve

4 Optional HHC connection –ve

5 Optional HHC connection +ve

7 Link to 8 to enable internal terminator

8 & 11 Safe-area fieldbus device(s) connection –ve

9 & 12 Safe-area fieldbus device(s) connection +ve

13 Supply –ve

14 Supply +ve

Note: To assist the process of terminating cable screens, screw terminals have been provided in terminals 3, 6, and 10. Please note, however, that there is no internal connection for these terminals so they are not earthed.

NOTE

To allow adequate heat dissipation under all likely thermal conditions, it is recommended that MTL5553s are installed on a horizontal DIN-rail mounted on a vertical surface\* with a 10mm space between adjacent units. MTL MS010 10mm DIN-rail module spacers are available for this purpose.

\* If an MTL5553 is mounted in a non-optimum orientation, the maximum operating temperature is reduced to 45°C.

INM 5500 Rev 1842

6 4 Analogue Input modules

The analogue input (AI) modules support 2-wire or 3-wire 4/20mA or HART transmitters located

in a hazardous area; repeating the current in other circuits to drive safe-area loads.

6 4 1 MTL5541/MTL5541-T/MTL5541S (-T) - Repeater Power Supply

Single channel, for 4/20mA HART® for 2- or 3-wire transmitters

The MTL5541 provides a fully-floating dc supply for energising a conventional 2- or 3-wire 4/20mA transmitter which is located in a hazardous area, and repeats the current in another

floating circuit to drive a safe-area load. For HART 2-wire transmitters, the unit allows bi-directional communications signals superimposed on the 4/20mA loop current.

Alternatively,

the MTL5541S (-T) acts as a current sink for a safe-area connection rather than driving a current into the load. Separately powered current sources, such as 4-wire transmitters, can be

connected but will not support HART communication.

Hazardous area Safe area

6

5

4  
3  
2  
1  
7  
8  
9  
10  
11  
12  
13  
14  
Vs–  
Vs+  
20 to 35V dc  
4/20mA  
MTL5541 MTL5541S

—  
4/20mA  
Load+ Load  
+  
—  
+  
Com  
Tx+  
Input  
|  
|  
-

Terminal Function  
1 Current input  
2 Transmitter supply +ve  
3 Common  
10 Output +ve via 220Ω for HART apps.  
11 Output –ve (+ve current sink)  
12 Output +ve (–ve current sink)  
13 Supply –ve  
14 Supply +ve  
Figure 6 20:  
Top labels  
for MTL5541  
& MTL5541S  
S

INM 5500 Rev 1843

## 6 4 2 MTL5541A/MTL5541AS - Repeater Power Supply

Single channel, for 4/20mA, HART® for 2- or 3-wire transmitters

The MTL5541A provides an input for separately powered 4/20mA transmitters and also allows

bi-directional transmission of HART communication signals superimposed on the 4/20mA loop

current. Alternatively, the MTL5541AS acts as a current sink for a safe-area connection rather

than driving a current into the load.

Hazardous area Safe area

Vs-

Vs+

20 to 35V dc

-

4/20mA

Load

+ -

+

MTL5541A MTL5541AS

Load +

—

+

4/20mA

6

5

4

3

2

1

7

8

9

10

11

12

13

14

I

I-

-

Terminal Function

1 Input -ve

2 Input +ve

11 Output –ve (+ve current sink)

12 Output +ve (–ve current sink)

13 Supply –ve

14 Supply +ve

Figure 6 21:

Top labels

for MTL5541A

& MTL5541AS

INM 5500 Rev 1844

6 4 3 MTL5544/MTL5544S - Repeater Power Supply

Two channel, for 4/20mA HART® for 2- or 3-wire transmitters

The MTL5544 provides fully-floating dc supplies for energising two conventional 2-wire or 3-wire 4/20mA or HART transmitters located in a hazardous area, and repeats the current in other circuits to drive two safe-area loads. For HART transmitters, the unit allows bi-directional

transmission of digital communication signals superimposed on the 4/20mA loop current.

Alternatively, the MTL5544S acts as a current sink for a safe-area connection rather than driving

a current into the load. Separately powered current sources, such as 4-wire transmitters, can

be connected but will not support HART communication.

Hazardous area Safe area

Vs–

Vs+

20 to 35V dc

–

4/20mA

Load

+

–

4/20mA

Load

+

Ch 2

Ch 1

MTL5544 MTL5544S

Load

+

–

Load

+

–

4/20mA

4/20mA

Ch 2

Ch 1

Com

Tx+

Input

Com

Tx+

Input

6

5

4

3

2

1

7

8

9

10

11

12

13

14

|

|

|

|

-

-

#### Terminal Function

1 Ch1 current input

2 Ch1 transmitter supply +ve

3 Ch1 common

4 Ch2 current input

5 Ch2 transmitter supply +ve

6 Ch2 common

7 Ch2 output +ve via 220 $\Omega$  for HART apps.

8 Ch2 output -ve (+ve current sink)

9 Ch2 output +ve (-ve current sink)

10 Ch1 output +ve via 220 $\Omega$  for HART apps.

11 Ch1 output -ve (+ve current sink)

12 Ch1 output +ve (-ve current sink)

13 Supply –ve  
 14 Supply +ve  
 Hazardous  
 area  
 Safe area  
 The MTL5544 or MTL5544S  
 can also be used to drive two  
 safe-area loads from a single  
 2-wire transmitter (i.e. 1 in,  
 2 out) by interconnecting the  
 input channels as shown in  
 the diagram (right).  
 Note: In this mode the HART  
 data is transferred via channel  
 1 output only.  
 See also the MTL5544D.  
 Vs–  
 Vs+  
 20 to 35V dc  
 –  
 4/20mA  
 Load  
 +  
 –  
 4/20mA  
 Load  
 +  
 Ch 2  
 Ch 1  
 MTL5544 MTL5544S  
 Load +  
 –  
 Load +  
 –  
 +  
 –4/20mA  
 6  
 5  
 4  
 3  
 2  
 1  
 7  
 8  
 9

10

11

12

13

14

|

|

|

|

Figure 6 22:

Top labels

for MTL5544

& MTL5544S

INM 5500 Rev 1845

6 4 4 MTL5544A/MTL5544AS - Current Repeater

Two channel, for 4/20mA passive input for HART® transmitters

The MTL5544A provides an input for separately powered 4/20mA transmitters and also allows

bi-directional transmission of HART communication signals superimposed on the 4/20mA loop

current. Alternatively, the MTL5544AS acts as a current sink for a safe-area connection rather

than driving a current into the load.

Hazardous area Safe area

Vs-

Vs+

20 to 35V dc

+

-

Ch 2

Ch 2

Ch 1

+

-

Ch 1

4/20mA

4/20mA

6

5

4

3

2

1

7

8

9

10

11

12

13

14

|

|

|

|

MTL5544A MTL5544AS

—

4/20mA

Load+

Load +

—

+

—

4/20mA

Load+

Load +

—

+

-

-

-

Terminal Function

1 Ch1 input -ve

2 Ch1 input +ve

4 Ch2 input -ve

5 Ch2 input +ve

8 Ch2 output -ve (+ve current sink)

9 Ch2 output +ve (-ve current sink)

11 Ch1 output -ve (+ve current sink)

12 Ch1 output +ve (-ve current sink)

13 Supply -ve

14 Supply +ve

Figure 6 23:

Top labels

for MTL5544A

& MTL5544AS

INM 5500 Rev 1846

6 4 5 MTL5544D - Repeater Power Supply

Two channel, for 4/20mA HART® for 2- or 3-wire transmitters, two outputs  
 The MTL5544D provides a fully-floating dc supply for energising a conventional 2- or 3-wire 4/20mA transmitter located in a hazardous area, and repeats the current in other circuits to drive two safe-area loads. For HART 2-wire transmitters, the unit allows bi-directional transmission of digital communication signals superimposed on the 4/20mA loop current via channel 1 only, Separately powered current sources, such as 4-wire transmitters, can be connected but will not support HART communication.

Hazardous area Safe area

Vs–

Vs+

20 to 35V dc

Ch 2

Ch 1

–

4/20mA

Load+

– 4/20mA

Load+4/20mA

6

5

4

3

2

1

7

8

9

10

11

12

13

14

Com

Tx+

Input

|

|

|

-

Terminal Function

1 Current input

2 Transmitter supply +ve

3 Common

7 Ch2 output +ve via 220Ω HART not supported.

8 Ch2 output –ve

9 Ch2 output +ve

10 Ch1 output +ve via 220Ω for HART apps.

11 Ch1 output –ve

12 Ch1 output +ve

13 Supply –ve

14 Supply +ve

NOTE: For correct operation of the module, a suitable load must be present on both output channels.

This is of particular importance during testing, commissioning or maintenance activities when the

temporary disconnection, or absence, of a load can affect the transfer accuracy of the analogue variable.

Figure 6 24:

Top label

for MTL5544D

INM 5500 Rev 1847

6 5 Analogue Output modules

The analogue output (AO) modules accept 4/20mA floating signals from safe-area controllers to

drive current/pressure converters (or any other load up to 800Ω) in a hazardous area.

6 5 1 MTL5546/MTL5546Y(-T) - Isolating Driver

Single channel, for 4/20mA HART® valve positioners with line-fault detection

The MTL5546 accepts a 4/20mA floating signal from a safe-area controller to drive a current/

pressure converter (or any other load up to 800Ω) in a hazardous area. For HART valve positioners, the module also permits bi-directional transmission of digital communication signals so that the device can be interrogated either from the operator station or by a hand-held

communicator. Process controllers with a readback facility can detect open or short circuits in

the field wiring: if these occur, the current taken into the terminals drops to a preset level.

The

MTL5546Y(-T) is very similar to the MTL5546 except that it provides open circuit detection only

(i.e. no short-circuit detection).

Hazardous area Safe area

-  
-  
-

-

-

#### Terminal Function

1 Output –ve

2 Output +ve

11 Input –ve

12 Input +ve

13 Supply –ve

14 Supply +ve

#### Input characteristics

Field wiring state MTL5546 MTL5546Y

Normal <6.0V <6.0V

Open-circuit <0.9mA <0.5mA

Short-circuit <0.9mA N.A.

Figure 6 25:

Top labels

for MTL5546

& MTL5546Y

INM 5500 Rev 1848

6 5 2 MTL5549/ MTL5549Y - Isolating Driver

Two channel, for 4/20mA HART® valve positioners with line-fault detection

The MTL5549 accepts 4/20mA floating signals from safe-area controllers to drive 2 current/pressure converters (or any other load up to 800Ω) in a hazardous area. For HART valve positioners, the module also permits bi-directional transmission of digital communication signals so that the device can be interrogated either from the operator station or by a hand-held

communicator. Process controllers with a readback facility can detect open or short circuits in

the field wiring: if these occur, the current taken into the terminals drops to a preset level.

The

MTL5549Y is very similar to the MTL5549 except that it provides open circuit detection only

(i.e. no short-circuit detection).

Hazardous area Safe area

-  
-

-

-

Terminal Function

1 Output –ve (Ch 1)

2 Output +ve (Ch 1)

4 Output –ve (Ch 2)

5 Output +ve (Ch 2)

8 Input –ve (Ch 2)

9 Input +ve (Ch 2)

11 Input –ve (Ch 1)

12 Input +ve (Ch 1)

13 Supply –ve

14 Supply +ve

Input characteristics

Field wiring state MTL5549 MTL5549Y

Normal <6.0V <6.0V

Open-circuit <0.9mA <0.5mA

Short-circuit <0.9mA N.A.

Figure 6 26:

Top labels

for MTL5549

& MTL5549Y

INM 5500 Rev 1849

6 6 Fire and Smoke Interface modules

Interfaces for use with conventional fire and smoke detectors located in hazardous areas.

6 6 1 MTL5561 - Fire and Smoke Detector Interface

Two channel

The MTL5561 is a loop-powered 2-channel interface for use with conventional fire and smoke detectors located in hazardous areas. In operation, the triggering of a detector causes

a corresponding change in the safe-area current. The unit features reverse input polarity protection.

Hazardous area Safe area

—

—

+

+

—

+

— +

Ch 2

Ch 1

Ch 2

Ch 1

6

5

4

3

2

1

7

8

9

10

11

12

13  
 14  
 |  
 |  
 |  
 |  
 Fire  
 detectors  
 Terminal Function  
 1 Output –ve (Ch 1)  
 2 Output +ve (Ch 1)  
 4 Output –ve (Ch 2)  
 5 Output +ve (Ch 2)  
 8 Input –ve (Ch 2)  
 9 Input +ve (Ch 2)  
 11 Input –ve (Ch 1)  
 12 Input +ve (Ch 1)  
 -

Figure 6 27:

Top label

for MTL5561

INM 5500 Rev 1850

6 7 Temperature Input module

These modules accept inputs from low-level dc sources such as thermocouples or RTDs in hazardous areas and converts them into 4/20mA signals to drive safe area loads.

Thermocouples Early burnout detection (EBD)

When EBD is selected, the resistance of the thermocouple circuit is monitored and an alarm is

raised when there is an increase of more than 50W. This enables preventative maintenance to

be conducted on the field installation before the thermocouple actually breaks.

Configuration using PCS45/PCL45USB

Use PCS45 software, in conjunction with the PCL45USB serial link, to configure these modules.

Instructions are contained within the software. See Section 6.9 on page 58 for further details.

All MTL5573 and MTL5575 modules are supplied with the following default configuration

Input type Type K thermocouple

Linearisation enabled

Units °C

CJ Compensation enabled

Damping value 0 seconds

Smoothing value 0 seconds

Output zero 0°C

Output span 250°C  
 Tag and description fields blank  
 Open circuit alarm set high (upscale)  
 Transmitter failure alarm set low (downscale)  
 CJ failure alarm set low (downscale)  
 Line frequency 50Hz  
 Use PCS45 software, in conjunction with the PCL45USB serial link, to modify these default values.  
 INM 5500 Rev 1851  
 6 7 1 MTL5573 - Temperature Converter  
 Single channel, THC or RTD input  
 The MTL5573 converts a low-level dc signal from a temperature sensor mounted in a hazardous area into a 4/20mA current for driving a safe-area load. Software selectable features include linearisation, ranging, monitoring, testing and tagging for all thermocouple types and 2-, 3- or 4-wire RTDs. (For thermocouple applications the HAZ-CJC plug on terminals 1–3 includes an integral CJC sensor). Configuration is carried out using PCS45 software, which is loaded onto a personal computer and connected via the PCL45USB serial link - see Section 6.9.  
 Top label  
 Use the following LED information to understand the module status.  
 Status PWR (green) STS(yellow)  
 Power ON ON  
 Insufficient voltage or Power OFF OFF  
 Normal working ON  
 Device failure FLASH  
 Sensor failure/Error FLASH  
 Early burnout detection (EBD) FAST FLASH ON  
 Hazardous area Safe area  
 Vs–  
 Vs+  
 20 to 35V dc  
 –  
 +  
 mV  
 4-wire  
 3-wire  
 Configuration  
 socket  
 Load  
 +  
 4/20mA  
 –  
 6  
 5

4  
3  
2  
1  
7  
8  
9  
10  
11  
12  
13  
14  
I  
mV

#### Terminal Function

1 THC/EMF/RTD input –ve  
3 THC/EMF/RTD input +ve  
4 3-wire RTD input –ve  
5 4-wire RTD input +ve  
11 Output –ve  
12 Output +ve  
13 Supply –ve  
14 Supply +ve  
3

Figure 6 32:

Top labels for  
MTL5573

INM 5500 Rev 1852

6 7 2 MTL5575 - Temperature Converter

Single channel, THC or RTD input with alarm

The MTL5575 converts a low-level dc signal from a temperature sensor mounted in a hazardous area into a 4/20mA current for driving a safe-area load. Software selectable features

include linearisation, ranging, monitoring, testing and tagging for all thermocouple types and 2,

3 or

4-wire RTDs. (For thermocouple applications the HAZ-CJC plug, on terminals 1–3, includes an

integral CJC sensor). Configuration is carried out using a personal computer - see section 6.9. A

single alarm output is provided and may be configured for process alarm or to provide notice of

early thermocouple failure.

Top label

Use the following LED information to understand the module status.

Status PWR (green) STS(yellow)

Power ON ON

Insufficient voltage or Power OFF OFF

Normal working ON

Device failure FLASH

Sensor failure/Error FLASH

Output relay ON (Trip) ON ON

Output relay OFF (Trip) ON OFF

Early burnout detection (EBD) FAST FLASH ON

Hazardous area Safe area

Terminal Function

1 THC/EMF/RTD input –ve

3 THC/EMF/RTD input +ve

4 3-wire RTD input –ve

5 4-wire RTD input +ve

8 Alarm relay

9 Alarm relay

11 Output –ve

12 Output +ve

13 Supply –ve

14 Supply +ve

-

-

-





Figure 6 28:  
Top label  
for MTL5575  
INM 5500 Rev 1853  
6 7 3 MTL5576-RTD - Temperature Converter  
Two channel, RTD input  
The MTL5576-RTD converts signals from resistance temperature detectors (RTDs) mounted in a hazardous area, into 4/20mA currents for driving safe-area loads. The MTL5576-RTD is compatible with 2- and 3-wire RTD inputs.  
Performance features, including input type and characterisation, ranging, monitoring, testing and tagging are selected using PCS45 software, which is loaded onto a personal computer and connected via the PCL45USB serial link - see Section 6.9.  
Hazardous area Safe area  
-  
-  
-



#### Terminal Function

1 RTD input (Ch1)

2 RTD input (Ch1)

3 3-wire RTD input (Ch1)

4 RTD input (Ch2)

5 RTD input (Ch2)

6 3-wire RTD input (Ch2)

8 Output -ve (Ch2)

9 Output +ve (Ch2)

11 Output -ve (Ch1)

12 Output +ve (Ch1)

13 Supply -ve

14 Supply +ve

-

-

-

#### Top label

Use the following LED information to understand the module status.

Status PWR (green) FLT (red) STS(yellow)

Power ON ON

Insufficient voltage or Power OFF OFF

Communication in progress FLASH

Normal working ON OFF OFF

Device failure ON ON

Channel 1 - Sensor failure/Error ON FLASH OFF

Channel 2 - Sensor failure/Error ON FLASH ON

Default configuration for both channels is as shown in 6.7 except S/C alarm set OFF.

Figure 6 29:

Top label

for MTL5576

INM 5500 Rev 1854

6 7 4 MTL5576-THC - Temperature Converter

Two channel, mV/THC input

The MTL5576-THC converts low-level dc signals from temperature sensors mounted in a hazardous area, into 4/20mA currents for driving safe-area loads. The hazardous area connections include cold-junction compensation and do not need to be ordered separately. Performance features, including linearisation for standard thermocouple types, ranging, monitoring, testing and tagging are selected using PCS45 software, which is loaded onto a personal computer and connected via the PCL45USB serial link - see Section 6.9.

Top label

Use the following LED information to understand the module status.

Status PWR (green) FLT (red) STS(yellow)

Power ON ON

Insufficient voltage or Power OFF OFF

Communication in progress FLASH

Normal working ON OFF OFF

Device failure ON ON

Channel 1 - Sensor failure/Error ON FLASH OFF

Channel 2 - Sensor failure/Error ON FLASH ON

Default configuration for both channels is as shown in 6.7 except S/C alarm set OFF.

Terminal Function

1 THC/mV (Ch1)

3 THC/mV (Ch1)

4 THC/mV (Ch2)

6 THC/mV (Ch2)

8 Output -ve (Ch2)

9 Output +ve (Ch2)

11 Output -ve (Ch1)

12 Output +ve (Ch1)

13 Supply -ve

14 Supply +ve

Hazardous area Safe area

-

-

-



-

-

-

Figure 6 30:

Top label  
for MTL5576  
INM 5500 Rev 1855

Please note that the safety drive on the MTL5581 responds to a line breakage (i.e. an open circuit) or a thermocouple burnout. It does not provide detection of a short circuit. It can however, when chosen, be set to drive the output either upscale or downscale. These options are selected using the switches located on the side of the module.

Safety drive switches Line  
breakage Vout valueSw2  
Safety drive  
Sw1  
Drive direction  
OFF N/A NO Vin\*  
OFF N/A YES undetermined  
ON + NO Vin\*  
ON + YES > +50mV  
ON – NO Vin\*  
ON – YES < –50mV

\* Within Vin/Vout transfer accuracy and drift error as specified in the product datasheet.

6 7 5 MTL5581 - mV/Thermocouple Isolator  
Single channel, mV/THC input for low power signals

The MTL5581 takes a low-level dc signal from a voltage source in a hazardous area, isolates it, and passes it to a receiving instrument located in the safe area. The module is intended for use with thermocouples utilising external cold-junction compensation. A switch enables or disables the safety drive in the event of thermocouple burnout or a cable breakage; a second switch permits the selection of upscale or downscale operation as the application requires.

Hazardous area Safe area  
PWR  
MTL5581  
Terminal Function  
1 THC/mV input –ve  
2 THC/mV input +ve  
11 Output –ve  
12 Output +ve  
13 Supply –ve  
14 Supply +ve  
OFF position  
ON position

Sw 1 Sw 2  
 Safety drive switches  
 Sw1 OFF ON Sw2 OFF ON  
 Drive direction '+' Upscale '-' Downscale Safety drive OFF ON  
 —  
 Vs—  
 Vs+  
 20 to 35V dc  
 +  
 Output\*  
 +  
 —  
 \*Use compensating  
 cable with  
 thermocouple inputs  
 6  
 5  
 4  
 3  
 2  
 1  
 7  
 8  
 9  
 10  
 11  
 12  
 13  
 14  
 mV  
 mVmV  
 Figure 6 31:  
 Top label  
 for MTL5581  
 INM 5500 Rev 1856  
 6 7 6 MTL5582/MTL5582B - Resistance Isolator  
 Single channel, to repeat RTD signals  
 The MTL5582 or MTL5582B connect to a 2-, 3-, or 4-wire resistance temperature device (RTD) or  
 other resistance located in a hazardous area, isolates it and repeats the resistance to a  
 monitoring  
 system in the safe area. The module is intended typically (but not exclusively) for use with  
 Pt100 3-wire  
 RTDs. Switches enable selection of 2-, 3-, or 4-wire RTD connection. The MTL5582/

MTL5582B should be considered as an alternative, non-configurable to MTL5575, for use in RTD applications where a resistance input is preferred or needed instead of 4/20mA. The design is notable for its ease of use and repeatability. The number of wires which can be connected on the safe-area side of the unit is independent of the number of wires which can be connected on the hazardous-area side. The module drives upscale in the case of open circuit detection. The MTL5582B replaced the MTL5582 during 2016 to improve the response characteristics of the safe area circuit.

Hazardous area Safe area

- 
- 

#### Terminal Function

1 RTD input –ve  
3 RTD input +ve  
4 3-wire RTD input –ve  
5 4-wire RTD input +ve  
9 RTD output –ve  
10 RTD output +ve  
11 RTD output –ve

12 RTD output +ve

13 Supply –ve

14 Supply +ve

PWR

MTL5582

OFF position

ON position

Sw 1 Sw 2

RTD type selection switches

Sw 1 Sw 2

2-wire OFF ON

3-wire ON ON

4-wire ON OFF

Warning: Check polarity of terminals used for safe-area connections. Safe-area terminals 9, 10, 11 and 12 are unipolar so it is essential to select a positive terminal on the MTL5582/MTL5582B for connection to the positive of the RTD input card.

Use the following LED information to understand the module status.

Status PWR (green)

Power ON ON

Insufficient voltage or Power OFF OFF

Sensor not connected FLASH

Input - Outside measuring range FLASH

Incorrect switch setting FLASH

Figure 6 32:

Top label

for MTL5582/

MTL5582B

INM 5500 Rev 1857

6 8 General modules

These are general purpose modules that have applications associated with the MTL5500 range of modules.

6 8 1 MTL5599 - Dummy Isolator

The primary function of the MTL5599, is to provide termination and earthing facilities for unused cable cores from hazardous areas, that can occur, for example, if any MTL5500 module

has been removed for maintenance purposes.

6 8 2 PSG60E24RM Power Supply

Terminals Function

L Mains input line

N Mains input neutral

E Earth

+ 24V dc +

- 24V dc-

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6 9 PCS45/PCL45USB configurator for MTL temperature converters

The PCS45/PCL45USB configurator allows MTL isolating temperature converters to be configured

from a standard PC running a Microsoft® Windows® operating system. The configurator comprises

PC software provided on a CD (PCS45), and an ATEX certified interfacing link (PCL45USB).

Temperature converters can be configured from the safe area, while on-line, and the software allows

configurations to be saved to disk and printed out when required.

It is suitable for use with MTL4000, MTL4500, MTL5000 and MTL5500 products.

PCL45USB hardware

The PCL45USB provides the interfacing link between the converter module and the PC running

the software and connects to the PC using the USB cable provided. The PCL45USB has a built-in

cable fitted with a 3.5mm jackplug to connect to the 'Config' socket on MTL4500 and MTL5500

converters. An adapter cable is also provided to accommodate our earlier converters.

PCS45 Configuration software

The software provided on the CD requires only approximately 20Mb of hard disk space and is

compatible with Windows 2000, Windows XP or Windows 7. Ensure that the chosen PC has a CD

ROM drive and an available USB port. A local or network printer may also be an advantage.

Safety

It is not permitted to connect the PCL45USB to any device other than one approved by Eaton.

Authorisation is valid provided that the converter type is named on the PCL45USB certificate or if

the PCL45USB is specified on the converter certificate. Repairs to the PCL45USB are not permitted.

Setting up

The equipment can be used only in the safe area.

Before plugging in the PCL45USB link to the computer, extract the USB driver files to a known

location on your PC. Afterwards, plug in the PCL45USB to the USB port on the PC and wait for

it to find the new device. When requested by the computer, show it the location of the driver

files so that it can complete the device installation.

Place the PCS45 software CD in the computer's CDROM drive and follow the on-screen instructions to install the software.

The PCL45USB is powered from the data lines and quickly establishes communication after

plugging the 3.5mm connector to the device socket.

Note: Ensure that the 3.5mm jack plug is fully inserted into the socket of the temperature converter.

The software and its operations manual (INM PCS45) is available on-line at:

[http://www.mtl-inst.com/product/configuration\\_tools\\_and\\_software/](http://www.mtl-inst.com/product/configuration_tools_and_software/)

Safe area

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## 7 FAULT FINDING AND ROUTINE MAINTENANCE

### WARNING

On removal, take care that a hazardous-area connector is not laid in a position in which it may inadvertently come into contact with safe-area circuit components

#### 7 1 Maintenance precautions

Most Codes of Practice for intrinsic safety permit live maintenance on intrinsically safe devices

and systems, provided precautions are taken to preserve the integrity of the device or system.

During live maintenance of MTL5500 modules, the hazardous-area connectors that plug into

the tops of the modules are likely to be removed. Avoid leaving a hazardous-area connector in a position where it may inadvertently contact non-IS circuits that are nearby. Prevent this by

providing some form of temporary mechanical method of securing the connector so that it cannot

come into contact with the non-IS circuits:

- a) By plugging the connector into an MTL5599 dummy isolator
- b) By using a tie-wrap to constrain the connector in a safe position.

#### 7 2 Fault finding

When fault finding, carry out the following steps as far as is necessary:—

##### 7 2 1

Check that all modules with power (PWR) LEDs are ON.

With the MTL5575 & MTL5576 models, a flashing LED indicates alarm or fault conditions, refer

to section 8. Note: The LED may also flash during intermediate stages of configuration.

##### 7 2 2

Exchange potentially faulty modules for working units as follows:—

- a) Unplug the hazardous-area connectors, then the safe area connectors.
- b) Unplug any power connectors and remove from DIN rail.
- c) Reverse this procedure to fit a replacement module.

##### 7 2 3

Potentially faulty modules should be tested in workshop conditions, using an appropriate test

procedure for the particular module as described in Section 8.

#### 7 3 Routine maintenance

Check the general condition of the installation occasionally to make sure that no deterioration

has occurred. Carry out the following at least once every two years and more frequently for particularly harsh environments:—

- a) Check that modules are of the types specified in the relevant documentation.
- b) Check that modules and hazardous-area connectors are correctly and legibly tagged, that the connectors are plugged into the matching modules and that the tag details given comply with the relevant documentation.
- c) Check that hazardous- and safe-area connectors are securely plugged into their matching sockets.
- d) Check that all connections to the connectors are properly made.
- e) Check that cables to connectors are of the specified type and rating, are correctly routed and segregated (particularly in Eaton enclosures), and are not frayed or otherwise damaged.
- f) Check that cable screens are properly earthed.

Note: It is strongly recommended that only the tests (described in Section 8) and routine maintenance (described here) should be undertaken by users. If a module is faulty, DO NOT attempt to make repairs or modifications as these may affect the intrinsic safety of the module.

All faulty units should be returned to the Eaton's MTL product line or representative from which

they were purchased, for repair or replacement.

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## 8 BENCH TESTING MODULES

The following methods have been devised to permit the user to perform simple module tests

on the bench and confirm basic input to output operation. Field units that do not perform as

described below, or modules that have 'unusual' operating behaviour, should be replaced and

returned to Eaton.

Consult individual module wiring diagrams for terminal connections.

Unless stated specifically, the module will require dc power, as if under normal operating conditions.

### 8 1 Digital Input (DI) modules

8 1 1 Modules: MTL 5501-SR, MTL5510, MTL5510B, MTL5511, MTL5513, MTL5514(-T), MTL5514D, MTL5516C, MTL5517

#### Input Conditions

1. Connect the appropriate input test circuit to the channel under test (see Figure 8 1 & Table 8 1).
2. For multi-channel modules with LFD, connect a 22kΩ resistor across the other channel input(s) to prevent the signalling of an unwanted open-circuit line fault.
3. Where appropriate test with phase reversal switch in both OFF and ON conditions.

-

-

Model Resistor values Switch – simulation conditions

MTL5501-SR R1 = 10k $\Omega$ , R2 = 1k4 $\Omega$

a) Normal - field switch open

b) Normal - field switch closed

c) Line Fault - Test for short circuit

d) Line Fault - Test for open circuit

MTL5510/5510B

MTL5511

MTL5513

MTL5514/5514D

MTL5516C

MTL5517

R1 = 22k $\Omega$ , R2 = 680 $\Omega$

Output Results

1. For MTL5510 and MTL5510B modules refer to pages 13-15 of this manual.

2. The phase reversal switch will reverse the channel output conditions, but not the LFD.

3. With LFD disabled (OFF) the Status LED should respond as shown in Table 8.2.

4. With LFD disabled (ON) the LEDs and relay should respond as shown in Table 8.3.

Input switch

positions

Channel contacts Status

LEDNC NO

a Closed Open OFF

b Open Closed ON

c Open Closed ON

d Closed Open OFF

Input switch

positions

Channel contacts LEDs LFD relay

NC NO Status LFD MTL550x MTL551x

a Closed Open OFF OFF Energised De-energised

b Open Closed ON OFF Energised De-energised

c Closed Open OFF ON De-energised Energised

d Closed Open OFF ON De-energised Energised

Figure 8 1:

DI input

test circuit

Table 8 1:

Input test  
conditions

Table 8 2:

Output test  
results

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8 2 Digital Output (DO) modules

Apply tests per channel.

8 2 1 Loop powered: - MTL5521(-T), MTL5522 & MTL5525

Figure 8 2: Loop powered DO test circuit

1. Connect a voltmeter between the + & – output terminals of the module, observing polarity.
2. Apply 24V between the supply terminals (Vs+, Vs–)
3. The voltmeter should indicate a value between 21.4 and 24 volts
4. Switch off the power to the module
5. Connect an ammeter between the + & – output terminals of the module, observing polarity
6. Apply 24V between the supply terminals (Vs+, Vs–)
7. The ammeter should indicate no more than 70mA for the MTL5522 and no greater than 48mA for any of the other modules
8. Switch off the power to the module

8 2 2 Powered:- MTL5523, MTL5523V, MTL5523VL & MTL5524

Figure 8 3: Powered DO test circuit

1. Connect a voltmeter between the + & – output terminals of the module, observing polarity
2. Apply 24V between the supply terminals Vs+, Vs–
3. The voltmeter should now include no more than 4V
4. Close the Control switch or, for the MTL5523V or MTL5523VL, apply the 24V source
5. The voltmeter should now indicate a value between 21.4 and 24 volts
6. Switch off the power to the module
7. Connect an ammeter between the + & – output terminals of the module, observing polarity
8. Close the Control switch or, for the MTL5523V or MTL5523VL, apply the 24V source
9. The ammeter should indicate no more than 48mA
10. Switch off the power to the module

8 2 3 Relay: - MTL5526

Figure 8 4: DO test circuit for relay type

1. Set in 2-channel mode (SW1 - SW4 respectively to Off, On, On, On)
2. Confirm continuity between NC and Common
3. Apply 24V between the supply terminals Vs+, Vs–
4. Close the Control switch
5. Confirm continuity between NO and Common
6. Switch off the power to the module

+

– Vs+  
 Vs–  
 i/po/pV A  
 +  
 – Controli/po/pV A  
 +  
 – 24V  
 +  
 –  
 MTL5523V/VL  
 Controli/po/p  
 +  
 –Common  
 NC  
 NO

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### 8 3 Analogue Input (AI) Modules

All of these tests compare the output current with the input current (A1) over the normal range of operation, and measure the “error current” i.e. the difference - as indicated on A2. Apply these tests per channel, as appropriate.

Ammeter A2 must be capable of handling either polarity. If it is not an auto-ranging instrument, set it to a high range before switch on, then adjust sensitivity to obtain the required reading.

8 3 1 Modules: MTL5541, MTL5544 & MTL5544D

Figure 8 5: AI test circuit #1

#### Output Measurements

Note: Do not connect a voltmeter in circuit to measure V1 until requested in Step 4 below, because current measurement A2 could be affected.

1. Adjust RV1 to vary the current (A1) through the range 4 to 20mA
2. The measured current imbalance (A2) over this range should not exceed  $\pm 20\mu\text{A}$
3. Adjust RV1 for a 20mA reading on A1
4. The voltage V1, across the channel input, should typically be  $>16.5\text{V}$ .

8 3 2 Modules: MTL5541S(-T), MTL5544S & MTL5561

Figure 8 6: AI test circuit #2 “o/p sinking”

#### Output Measurements

Note: Do not connect a voltmeter in circuit to measure V1 until requested in Step 4 below, because current measurement A2 could be affected.

1. Adjust RV1 to vary the current (A1) through the range 4 to 20mA.
2. The measured current imbalance (A2) over this range for the MTL5541S and the MTL5544S should not exceed  $\pm 20\mu\text{A}$ . For the MTL5561 the imbalance should not exceed  $\pm 400\mu\text{A}$ .
3. Adjust RV1 for a 20mA reading on A1

4. The voltage V1, across the channel input, should typically be >16.5V.

-  
-  
-

-

+

-

+

-

+—

V1 i/p o/p

RV1

10k $\Omega$  lin.

A1

250 $\Omega$

24V

+

-

I oli A2

+

-

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8 3 3 Modules: MTL5541A & MTL5544A

Figure 8 7: AI test circuit #3 “active i/p”

Output Measurements

1. Adjust RV1 to vary the current (A1) through the range 4 to 20mA.
2. The measured current imbalance (A2) over this range should not exceed  $\pm 20$ mA

8 3 4 Modules: MTL5541AS & MTL5544AS

Figure 8 8: AI test circuit #4 “active i/p - o/p sinking”

Output Measurements

1. Adjust RV1 to vary the current (A1) through the range 4 to 20mA.
2. The measured current imbalance (A2) over this range should not exceed  $\pm 20$ mA

-

-

-

-

-

-

-

-

-

-

-

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8 3 5 Module: MTL5581

Figure 8 9: AI test circuit #5 “mV input”

Note: V1 should be capable of measurement to within 1mV.

Output Measurements

1. With the LINK connected, vary output V2 between 0 and 50mV using RV1. V1 should show

<50mV variation. (Note: Safety Drive can be ON or OFF )

2. With the LINK disconnected and Safety Drive ON, V2 should drive to >+50mV with the switch set to ‘+’, or <-50mV with the switch set to ‘-’.

8 3 6 Module: MTL5582/5582B

Figure 8 10: AI test circuit #5 “Resistance input”

Output Measurements

1. Set Sw1 & Sw2 to ON for 3-wire operation. Set the resistance box to any value between 10

and 400W and switch on power supply.

2. The green PWR LED should go to a steady state after initially flashing. If the flashing does not

stop after 5 seconds then either the setup wiring is faulty or the unit is faulty.

3. Vary the resistance box setting between 10 and 400Ω and confirm the output voltage varies.
4. Short circuit the input and check that the output voltage is  $\leq 51.6\text{mV}$  after 5 seconds.
5. Open circuit the input and check that the output voltage is  $\leq 2.071\text{V}$  after 5 seconds and that the green PWR LED is flashing.
6. Set the input resistance to 200Ω and check that the output voltage settles to  $1.0\text{V} \pm 32\text{mV}$

-

-

-

+

—

+

—

i/p

o/p

Resistance

box

0 - 400Ω min.

5.0mA  $\pm$  150μA

47mV - 2.100V2-wire

3-wire

4-wire

—

V

+

9

10

11

12

1

3

4

5

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#### 8 4 Analogue Output (AO) Modules

The test compares the output current with the input current over the normal range of operation.

##### 8 4 1 Modules: All variants

##### Input Conditions

The chosen "load" resistor can be any value between 100 and 800Ω.

Figure 8 11: AO test circuit

##### Output Measurements

1. Adjust the current source to vary the current (A1) through the range 4 to 20mA.
2. The measured current imbalance (A2) over this range should not exceed  $\pm 20\text{mA}$ .

#### 8 5 Testing the functioning of other modules

Simple tests to verify their basic operation can be devised for other modules (e.g. temperature, pulse, vibration, etc). If any assistance is required for the testing of a particular module, please

contact the technical support department at Eaton for advice.

##### 8 5 1 Testing

Make the safe- and hazardous-area connection shown in figure 8.12.

Figure 8 12: Test circuit for MTL5531

Measure the voltage on terminal 3 with respect to terminal 1; this should be  $>19\text{V}$ . Vary the potentiometer setting and check that the reading on voltmeter V varies by no more than  $\pm 100\text{mV}$ .

+  
— +

—  
A2

+  
—

A1  
o/p i/p  
current  
source

+—  
470Ω  
load

I oli

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#### 8 5 2 Testing MTL5553 - Isolator/power supply for 31 25kb/s fieldbuses

Make the safe and hazardous-area connections shown in figure 10.2 and, substituting appropriate

resistors at Rtest, carry out the following checks.

Rtest Voltage across terminals 2 and 1 (V1)

Open-circuit  $17.8 < V1 < 19\text{V}$

220Ω 11.5V < V1 < 13.5V

10Ω V1 < 5V

20-35V dc

Vs-

Vs+

-ve

+ve

-ve

Host

(31.25kbit/s)

Terminator

1

2

4

5

6

3

2.6W Max

8

9

T

14

13

11

10

7

12

Link 7- 8 for Terminator

Hazardous Area Safe Area

V1 R test

+

-

Top Label, MTL5553

Test circuit for MTL5553

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9 APPLICATIONS INVOLVING ZONE 2 AND/OR ZONE 22

HAZARDOUS AREAS

IMPORTANT: See page iv at the front of this manual for important additional information regarding

the use of these products in countries governed by the ATEX Directive.

The European Community permits Category 3G equipment, such as the MTL5500 , to be installed

in, or connected to, Zone 2 flammable atmospheres provided it meets the requirements of the

ATEX Directive.

MTL5500 Category 3 products have been designed to meet, and carry approval markings for,

Ex nC and/or Ex nA.

In general, meeting the relevant requirements of the appropriate European (CENELEC) standards is considered the most appropriate method of demonstrating compliance with the

ATEX directive. However, Eaton often has its products approved by other national bodies, such

as FM and CSA and, because national, European, and international standards are converging, it is

generally possible to use other national approvals as supporting evidence for the ATEX Technical

File.

In the context of this document, Zone 2 (Division 2) and Zone 22 hazardous areas are those that may become potentially explosive through the presence of flammable gases, vapours and

dusts for periods of up to 10 hours per year. It is recommended that the current version of the

standards is consulted for detailed information on the requirements applicable to the particular

installation.

As a consequence of their IS approvals, MTL5500 products may also be connected into Zone 22

hazardous areas. Consult individual module approvals for further details.

Unless otherwise specified, the following ambient conditions apply:

Ambient Temperature range  $-20^{\circ}\text{C}$  to  $+60^{\circ}\text{C}$

Pollution Degree 2 (See EN 61010-1)

Measurement Category II (See EN 61010-1)

9 1 Enclosure

EN 60079-15 specifies the minimum required degree of protection to be IP54, but generally this

is provided by the external enclosure in which the product is mounted.

The user must refer to the specific certificates relating to the products being installed within the

hazardous area to check that all special conditions of safe use have been complied with.

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10 APPENDIX 1

10 1 MTL5000

Many modules in the MTL5000 Isolating Interface Units range have now been superseded by their equivalent in the MTL5500. For new applications the MTL5500 modules are recommended, these offer all the benefits of greater efficiency, new multichannel modules and new functionality.

A number of the products in the MTL5000 will continue to provide key functionality as part

of

MTL DIN rail isolator range and are described within this Appendix.

#### Important

- Make sure that all installation work is carried out in accordance with all relevant local standards, codes of practice and site regulations.
- When planning the installation of MTL5000 isolators it is essential to make sure that intrinsically safe and non-intrinsically safe wiring is segregated, and that units are installed as required by a nationally accepted authority or as described in EN 60079-14, ISA RP 12.6 or DIN VDE-165.
- Check that the hazardous-area equipment complies with the descriptive system document.
- If in doubt, refer to the certificate/catalogue for clarification of any aspects of intrinsic safety or contact Eaton's MTL product line or your local representative for assistance.
- Make sure the correct hazardous-area connector (field-wiring plug) is plugged into the corresponding isolator. It is recommended that the connector is identified by the same tag number as the matching isolator.

Mount all MTL5000 isolators on low-profile (7mm) or high-profile (15mm) type T35 (top-hat) DIN-rail to EN50022, BS5584, DIN46277. This is available from Eaton, in 1 metre lengths (THR2 - DIN rail). Install isolators within the safe area unless they are enclosed in approved flameproof, pressurised or purged enclosures and ensure that the local environment is clean and free of dirt and dust. Note the ambient temperature considerations of section 3.1.4.

It is recommended that, in normal practice, the DIN rail should be earthed/grounded to ensure the safety of personnel in the event of a.c. mains (line) power being applied accidentally to the rail.

#### Power

connectors

104

115

110

16

16.2mm PITCH

HAZ SAFE

Hazardous-area

connections

Non-hazardous

(safe) area

connections

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10 2 MTL5018AC single-pole, changeover relay,  
two-channel, switch/proximity detector with line fault detection  
and phase reversal

The MTL5018AC modules enable each of two safe-area loads to be relay-controlled by

switches

or proximity detectors in a hazardous area.

Line fault detection (LFD) and output phase reversal facilities are included (see section 6.1).

#### 10 2 1 Wiring connections

See figure 10.1 for wiring connections.

Note: Reactive loads must be adequately suppressed.

#### 10 2 2 Line fault detection

(See section 6.1 for definition of a line fault)

On each channel, input line faults (open- or short-circuit) are indicated by an LED and the de-energising of the output. LFD is enabled/disabled by switches located on the top of the module.

Note: that if the LFD facility is enabled for switch inputs, the resistors shown in 10.1 and 10.2

MUST be fitted.

#### Terminal Function

1 Input –ve (Ch 1)

2 Input +ve (Ch 1)

3

4 Input –ve (Ch 2)

5 Input +ve (Ch 2)

6

7 Normally-closed contact (Ch 2)

8 Common (Ch 2)

9 Normally-open contact (Ch 2)

10 Normally-closed contact (Ch 1)

11 Common (Ch 1)

12 Normally-open contact (Ch 1)

13 Supply N

14 Supply L

#### Hazardous area Safe area

Figure 10 1: MTL5018AC wiring diagram and connections

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#### 10 2 3 Testing

Make the safe- and hazardous-area connections shown in figure 10.2, and check the status of the output contacts for each channel in turn (with a 22k $\Omega$  resistor connected to the other channel) as shown in the table 10.1.

Phase

reverse

switch

Line

fault

detection

Input

switch

(SW)

Output

relay

(11-12, 8-9)

Output

relay

(10-11, 7-8)

Channel

status LED

(yellow)

Line fault

LED

(red)

Normal Off a Closed Open On Off

Reverse Off ISC = 7 \_ 9mA Open Closed Off Off

Reverse Off Open Closed Open Off Off

Normal On VOC = 7.5 \_ 9.5V Open Closed Off On

Normal On a Open Closed Off On

Normal On b Open Closed Off Off

Normal On c Closed Open On Off

Figure 10 2: Test circuit for MTL5018AC

Table 10 1

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10 3 MTL5051 serial data comms isolator

The MTL5051 provides either bi-directional serial data communications from a computer system

in a safe area to instrumentation in a hazardous area or data communications across a hazardous area. It is used to provide a fully floating dc supply for, and serial data communications to MTL640 text displays and MTL650 text and graphics terminals or to other

IS and non-IS instrumentation and keyboards.

10 3 1 Wiring connections

See the figures 10.3 and 10.4 and the terminal specifications in tables 10.2 and 10.3 for wiring connections.

Figure 10.3: MTL5051 wiring diagram (to a hazardous area)

Hazardous area Safe area

Safe areaHazardous area

Figure 10.4: MTL5051 wiring diagram (across a hazardous area)

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10 3 2 Hazardous-area interfacing

Displays/terminals: For details of interfacing with MTL640 and MTL650 displays/terminals (as

an alternative to the MTL696 communications interface) see the appropriate product

instruction  
manual.

Table 10 2

MTL5051

Terminals

MTL640

mode

MTL650

mode

Comms

mode

Other IS

devices

1 Common Common Common Common

2 V signal 12V - 5V/12V

3 I return Rx Rx -

4 - Tx Tx -

5 - - - Tx

6 - - - Rx

Switch

1a On Off Off Off

1b On On On Off/On

Table 10 3

Terminals RS232 mode TTL mode RS422 mode

7 - - Rx-

8 - - Rx+

9 - Tx Tx+

10 Tx - Tx-

11 Common Common Common

12 Rx Rx -

13 Supply -ve Supply -ve Supply -ve

14 Supply +ve Supply +ve Supply +ve

Switch

2a Off On On

2b On Off Off

Across hazardous areas: For communication across hazardous areas MTL5051 devices are used

in pairs to transfer bi-directional full duplex data across hazardous areas, as shown in figure 10.4. Current switching is used to minimise the bandwidth-limiting effects of long cables. The maximum baud rate in this mode is the lesser of 19.2k baud or the cable-related rate produced by the following formula.

Remote signalling baud rate formula, for back-to-back mode across a hazardous area:

max baud rate =  $K/(R_x C_x L^2)$

where K = 0.25 (constant)

R = cable resistance ( $\Omega/\text{m}$ )

C = cable capacitance (F/m)

L = length (m)

For example, with a 2km cable of 100pF/m capacitance and 40m $\Omega$ /m resistance, the maximum

baud rate =  $0.25/(40\text{m}\Omega \times 100\text{pF} \times 2\text{km}^2) = 15\text{k}$  baud. This assumes that the cable is 2 cores plus screen, with the screen used for the 'common' connection.

RS232-level devices: Communication with RS232-level interfaces, such as a suitably certified IS keyboard, mouse, etc, is achieved by using one or more MTL5051 units as required by the IS

device. (TTL level interfaces are accommodated by the TTL compatibility of RS232 receivers.)

The supply to IS equipment at terminal 2 can be set to either 5V or 12V, by a switch located on

top of the unit, as follows:

+12V mode 12.0V  $\pm 5\%$  (load <23mA)

+12V mode 8.0V min (load >23mA to <50mA)

+5V mode 5.6V  $\pm 5\%$  (load >23mA to <50mA)

Note: the normal RS232 limitations of bandwidth versus cable length are applicable. As a rule

of thumb, speed (baud)  $\times$  length (metres) <150,000.

Figure 10 5:

Top label

for MTL5051

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10 3 3 Testing

Remove all safe- and hazardous-area connections and apply 24V dc to terminals 13 and 14 as shown in figure 10.6. Check that the green power LED (on top of the unit) is on. Put all switches in the On position. With no load, check for nominal current of 60mA  $\pm 5\text{mA}$  at terminal 14. Correct operation of the communication modes is indicated by signals received and/or transmitted.

dc supply

-

+

Figure 10 6: Test circuit for MTL5051

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10 4 MTL5314 trip amplifier for 2- or 3- wire transmitters

The MTL5314 connects to a 2- or 3- wire 4 to 20mA transmitter or current source located in the hazardous area. It supplies one or two configurable alarm signals to the safe area via changeover relays. Each relay may be configured individually to signal an alarm condition when

the input signal is greater than or less than a pre-set value.

In addition, the MTL5314 can be connected in to the hazardous area side of an MTL5541/ MTL5541S 4 to 20mA repeater power supply (or equivalent device) to provide two trip alarm

outputs direct from the transmitter signal (see schematic diagram). Looping the transmitter signal through the MTL 5314 (via terminals 1 and 3) does not affect HART® communications. Terminals 1 and 3 meet clause 5.4 of EN50020: 1994 and have the following parameters:  $U \leq 1.5V$ ,  $I \leq 0.1A$ ,  $P \leq 25mW$ . They can be connected without further certification into an IS loop with open circuit voltage of not more than 28V. See certificate for further details.

#### 10 4 1 Wiring connections

If terminals 1 and 3 provide a 4 to 20mA loop to a HART transmitter, HART communication can

be superimposed on the 4 to 20mA signal.

Note: Reactive loads must be adequately suppressed.

Figure 10.6: MTL5314 wiring diagram and connections

Hazardous area Safe area

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#### 10 4 2 Trip calibration

Switches and multiturn potentiometers for setting the trip points are located on top of the unit

(see figure 10.7). For each of channels A and B:

i Set trip switch to H (high) or L (low) as required (see table 10.4 for relay operation).

ii Set input current to the required value for trip-point.

iii Adjust SET A/SET B until LED A/B is on: then slowly adjust until LED goes out.

iv Relays are energised in normal operation and de-energised when tripped. A lit LED shows the safe condition (not tripped).

Table 10 4

Trip

switch

A or B

Operation PWR

LED

A or

B

LED

Relay contacts

11 - 12

8 - 9

10 - 11

7 - 8

H (high) Input > trip setting • open closed

H (high) Input < trip setting closed open

L (low) Input > trip setting closed open

L (low) Input < trip setting • open closed

-- • • open closed

Terminal Function

1 Current input

2 Transmitter supply +ve

3 Common

7 Trip B (NC)

8 Trip B (COM)

9 Trip B (NO)

10 Trip A (NC)

11 Trip A (COM)

12 Trip A (NO)

13 Supply -ve

14 Supply +ve

Figure 10 7:

Top label

for MTL5314

INM 5500 Rev 1876

10 4 3 Testing

Make the safe- and hazardous-area connections shown in figure 10.7 and carry out the following procedure:

a Set the current source or sink to 12mA

b Adjust each trip potentiometer until the associated LED just extinguishes.

c With sources of 11.5mA and 12.5mA carry out the following checks:

Table 10 5

Current High alarm Low alarm

Relay Relay

LED 11 - 12

8 - 9

10 - 11

7 - 8

LED 11 - 12

8 - 9

10 - 11

7 - 8

11.5mA On closed open Off open closed

12.5mA Off open closed On closed open

Figure 10.7: Test circuit for MTL5314

INM 5500 Rev 1877

11 APPENDIX:

11 1 Table A - Safety descriptions

All models are  $U_m = 253V$

Model No

Terminals/

Bornes/Klemme/

## Terminales

Uo

(V)

Io

(mA)

Po

(mW)

MTL5501-SR 9.7 30 70

MTL5510 / MTL5510B / MTL5511

MTL5513 / MTL5514

MTL5514D / MTL5516C

MTL5517

10.5 14 37

MTL5521 25 147 920

MTL5522 25 166 1040

MTL5523 / MTL5523V 25 147 920

MTL5523VL 25 108 680

MTL5524 25 147 920

MTL5525 25 83.3 521

MTL5526 1 3, 4 6 Non-energy storing \*

MTL5531 3 1 26.6 94 660

3 2 1.1 0.1 0.03

MTL5532

2 1, 6 1 10.5 14 37

3 1 1.1 53 15

4 + 3 1 28 93 @ 28V

146 @ 2.9V 650

5 + 4 1 28 9 650

config † Uo = 8

Ui = 9.1 15 27

MTL5541 28 93 650

MTL5541A / MTL5541AS 8.6

(diode) --

MTL5544 / MTL5544S 28 93 650

MTL5544A / MTL5544AS 8.6

(diode) --

MTL5544 / MTL5544D / MTL5544S

MTL5546 / MTL5546Y / MTL5549

MTL5549Y / MTL5561

28 93 650

MTL5553 22 216 1200

MTL5573

1 2 3 4 5 6 6.6 76 130

3 1 Non-energy storing \*

3,2 & 1 6.6 10 17

config † Uo = 8

Ui = 9.1 14.6 26

MTL5575

1 2 3 4 5 6 6.6 76 130

3 1 Non-energy storing \*

3,2 & 1 6.6 10 17

config † Uo = 8

Ui = 9.1 14.6 26

MTL5576

1,2 & 3, 4,5,& 6 6.6 28 46.2

3 1, 6 4 Non-energy storing \*

config † Uo = 5.88

Ui = 9.1 12 17.7

MTL5581 Uo = 1.1

Ui = 28

Io = 53

li = 120 15

MTL5582

1,3,4 & 5 6.6 42 69.3

1,3 & 4 6.6 28 46.2

3 1 Uo = 1.2

Ui = 5 4 1.2

config † Uo = 6.68

Ui = 9.1 12 17.7

MTL5582B

1,3,4 & 5 6.51 16 16.1

1,3 & 4 6.51 6 9.2

3 1 Uo = 1.2

Ui = 5 4 1.2

config † Uo = 1.2

Ui = 5 12 17.7

\*Non energy storing apparatus ( $\leq 1.5V$ ;  $\leq 0.1A$ ;  $\leq 25mW$ )

† config - configuration socket

Note: Certificate IECEx TSA 20.0021 includes all models listed above except MTL5523V, MTL5523VL, MTL5546Y and MTL5553.

INM 5500 Rev 1878

Model No Terminals/

Bornes/

Klemme/

Terminales

Group/Groupe/Gruppe/Grupo

|

Group/Groupe/Gruppe/Grupo

IIB / IIIC

Group/Groupe/Gruppe/Grupo

IIC

C

( $\mu$ F)

L

(mH)

L/R

( $\mu$ H/ $\Omega$ )

C

( $\mu$ F)

L

(mH)

L/R

( $\mu$ H/ $\Omega$ )

C

( $\mu$ F)

L

(mH)

L/R

( $\mu$ H/ $\Omega$ )

MTL5501-SR 320 501 6,414 24 145 1,829 3.5 39 475

MTL5510 / MTL5510B

MTL5511 / MTL5513

MTL5514 / MTL5514D

MTL5516C / MTL5517

95 1000 1,333 16.8 680 1333 2.41 175 983

MTL5521 4.87 20.2 478 0.84 7.2 159 0.11 1.4 40

MTL5522 4.87 16.0 428 0.84 5.6 132 n/a n/a n/a

MTL5523 / MTL5523V 4.87 20.2 478 0.84 7.2 159 0.11 1.4 40

MTL5523VL 4.87 40.0 691 0.84 12.19 210 0.11 3.04 52

MTL5524 4.87 20.2 478 0.84 7.2 159 0.11 1.4 40

MTL5525 4.87 64.9 814 0.84 21.8 254 0.11 5.3 68

MTL5526 1 3, 4 6 - - - - -

MTL5531

3 1 4.27 52.81 746 0.73 16.09 227 0.094 4.02 56

3 2 1,000 1,000 1,000 1,000 1,000 1,000 100 1,000 1,000

MTL5532

2 1, 6 1 95.0 1,000 1,333 16.8 725.6 1,333 2.41 181.4 967

3 1 1,000 166.1 32,018 1,000 50.6 9,757 100 12.6 2,439

4 + 3 1 3.76 21.8 668 0.65 6.67 210 0.083 1.66 55

5 + 4 1 3.76 52.8 668 0.65 16.0 210 0.083 4.02 55

config † 12.32 797.5 1,484 2.15 243.0 1,441 0.367 60.7 360

MTL5533 3 1, 6 4 4.27 52.81 746 0.73 16.09 227 0.094 4.02 56

3 2, 6 5 1,000 1,000 1,000 1,000 1,000 1,000 100 1,000 1,000  
 MTL5541 / MTL5541S  
 MTL5544 / MTL5544D  
 MTL5544S  
 2 1, 5 4 3.76 53.7 668 0.65 12.6 210 0.083 4.2 56  
 3 1, 6 4 1,000 156.2 28,229 1,000 47.8 8,932 100 12.8 2,438  
 2 3, 5 6 3.76 59.1 710 0.65 20.2 222 0.083 4.9 59  
 MTL5541A / MTL5541AS 2 1, 5 4 1,000 65.82 17,740 55 20.06 5,406 6.2 5.01 1,351  
 MTL5544A / MTL5544AS  
 2 1, 5 4 1,000 65.82 17,740 55 20.06 5,406 6.2 5.01 1,351  
 501 (Ch 1&2  
 series) 12.16 65.82 8,870 2.11 20.06 2,703 0.36 5.01 675  
 MTL5546 / MTL5546Y  
 MTL5549 / MTL5549Y  
 MTL5561  
 2 1, 5 4 3.76 53.7 668 0.65 12.6 210 0.083 4.2 56  
 MTL5553 6.0 9.54 392 1.14 0.79 119 0.165 0.26 29  
 MTL5573 1+2+3+4+5+6 1,000 77.2 3,402 500 25.6 1,057 22 6.42 288  
 config † 12.32 1,000 1,453 2.15 591 1,355 0.367 153 349  
 MTL5575 1+2+3+4+5+6 1,000 77.2 3,402 500 25.6 1,057 22 6.42 288  
 config † 12.32 1,000 1,453 2.15 591 1,355 0.367 153 349  
 MTL5576 1 to 4 1,000 264.5 6,363 500 80.6 2,052 22.0 20.1 513  
 1,2 & 3  
 4,5 & 6  
 500 297.6 2,121 250 90.7 1,537 11.0 22.6 384  
 3 1, 6 4 500 500 1,666 500 500 1,666 50 500 1,666  
 config † 15.8 1,000 1,412 2.88 317.9 1,412 0.478 79.4 448  
 MTL5581 1,000 155.7 28,229 1,000 47.3 8,932 100 12.3 2,438  
 MTL5582 1, 3, 4 & 5 1,000 264.5 6,363 500 80.6 2,052 22.0 20.1 513  
 1, 3 & 4 1,000 595.2 4,242 500 181.4 3,078 22.2 45.3 769  
 3 1 1,000 1,000 3,333 1,000 1,000 3,333 100 1,000 3,333  
 config † 15.8 1,000 1,412 2.88 317.9 1,412 0.478 79.4 448  
 MTL5582B 1, 3, 4 & 5 1,000 1,000 1,536 500 1,000 1,536 22.0 355.5 1,536  
 1, 3 & 4 1,000 1,000 921 500 1,000 921 22.0 987.6 921  
 3 1 1,000 1,000 3,333 1,000 1,000 3,333 100 1,000 3,333  
 config † 15.8 1,000 1,412 2.88 317.9 1,412 0.478 79.4 448  
 † config - configuration socket  
 Note: Certificate IECEx TSA 20.0021 includes all models listed above except MTL5523V,  
 MTL5523VL, MTL5546Y and MTL5553.  
 11 2 Table B – Maximum cable parameters  
 INM 5500 Rev 1879  
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2024-79405	Senior Power Electronics Architect	Not Selected	11/12/2024	
2023-62576	Energy Sourcing Analyst	Not Selected	11/6/2024	
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2024-79092	Power Systems Medium Voltage Intern	Not Selected	10/23/2024	

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Senior Design Engineer- Electro Mechanical - 0095Z8

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**Developing design proposals, specifications, product selection, drawings, calculations, and other data to evaluate the feasibility, cost implications, and maintenance requirements of designs or applications.**

SEE will provide design solutions to meet the customer and site requirements, and ensure the customer's best interests are protected during the project. Relies on experience and judgment to plan and accomplish goals. Facilitate meetings and interviews with customer and sub-consultants.

Able to handle different type of projects, tendering support, customer execution projects, R&D projects and quick efforts, quality support, services support.

#### **RESPONSIBILITIES:**

##### **Tender Phase:**

- o Participates in the programming of the project with the customer or customer representative to understand and document the owner's project requirements. Influence on solution to drive.

- o Understand the codes and ordinances local to the opportunity/project.
- o Solutions Development: Provide appropriate design documents to support the proposal and allow the estimating team to assemble cost for the proposal. These design documents should identify at a minimum the following as applicable:

Identification of major infrastructure equipment

Bid specifications for the major/long lead equipments.

Space, clearances and site layout.

Systems diagrams, grounding, calculations, ventilation, gas exhaust, protection relays, others.

- o Provide review of major equipment quotes for technical compliance from vendors. (Estimating team shall be responsible for soliciting and gathering the quotes)
- o Provide estimate to develop the final design documents and construction administration as appropriate for the project.
- o Solicit, review, and approve sub-consultant proposals to provide a complete set of design documents for the project.
- o Provide the technical narrative for the critical infrastructure to be incorporated into the proposal, sequence of operations, range of settings.

**Design Phase:**

- o Perform code analysis for the project.
- o Take the lead for the basis of design for the project, including redundancy requirements, detailed design, detailed calculations, validate product selection, etc.
- o Engineering support function, supporting requests from other engineering teams, factory, commissioning, sub-contractors, services, site support.
- o Support on System sequence of operation (SOO)
- o Contributes to team effort by accomplishing related results as needed.

**Construction Phase:**

- o Provide support and response to request for information and factories support.
- o Validate internal and external factories & subcontractors design, i.e. approval for multiwiring diagrams, product optionals, others.
- o Participate in recurring construction meeting as required.
- o Assist the construction team during construction team for clarification, changes, corrections, value engineering, etc.
- o Provide assistance to the construction team for change order requests
- o Provide as-builts drawings at the end of the project from redlines provided by the construction team and site verification.

**SKILLS & CAPABILITIES:**

- o Maintains professional and technical knowledge by attending educational workshops; reviewing professional publications; establishing personal networks; participating in professional societies.
- o Attend new products trainings and events to improve knowledge and capabilities.
- o Prepare and schedule trainings as a SME (Subject Matter Expert) to other engineers
- o Social media, internal networking, ability to work in international environment. Teamwork skills.
- o Being familiar with a variety of the field's concepts, practices and procedures.

**SECONDARY FUNCTIONS:**

- o Travel to customer sites experiencing issues to support the technical resolution .
- o Participate in Offer Safety related meetings.

## **EDUCATION, EXPERIENCE & SKILLS**

- o Good English speaking, written and verbal skills.
- o Good Spanish speaking, written and verbal skills.
- o Good Communication skills
- o Good capability to work in a Multi Discipline Engineering team
- o Good acknowledge on Schneider Medium Voltage portfolio.
- o Good acknowledge on medium voltage products and safety standards.
- o Good capability to work with Microsoft tools, REVIT & CAD.
- o 5 years of experience in MV Power Systems Design.
- o Data Center design experience.
- o Experience on simulation tools such as ETAP or Caneco HT.
- o MV/LV coordination, arc flash gassing simulation / study.
- o Knowledge on Protective relays configuration.
- o Background in LV power designs.

Primary Location

: IN-Karnataka-Bangalore

**Senior Manager MES & Automation - 0099L0**

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Work on Conversion of Legacy MES to STD MES Existing Lines/Process for Region

Ensure all New Projects/Lines/ Machines are launched with STD MES inbuilt within region

Train and Develop Resources on development of STD MES Applications within Region.

Work with Open IT/MDC teams on PMS Enhancements and Connections with Other Digital Tools

Takes care of all Cybersecurity requirements

- Supports MDC Automation team on projects when needed.

AREAS OF RESPONSIBILITY	LEVEL	MEASUREMENT
(Describe the nature, scope, level of improvements to new ideas, etc.)	*(Full, Partial, Supportive)	(Quantitative or quality criteria to achieve responsibility)
<b>Project management Skills</b>		
Align each location execution plan with global roadmap.		
Plan the detailed Implementation activities	Full	100% Completion
Follow up with team for execution roadmap		
Identify the risks in project and mitigate it.		
Integration with different stockholders (Plant, Central team, MDC Team + Open IT		

<p>Team Interactions) for smooth execution on project</p> <p>Budgeting &amp; Cost control</p> <p>Project Handover</p>		
<p><b>PMS ( MES ) Skills</b></p> <p>PMS Data &amp; Web UI Server installation &amp; configuration</p> <p>PMS Runtime Server installation &amp; configuration</p> <p>PMS Line/Workstation setup</p> <p>Product/Recipe configuration in PMS</p> <p>PMS Database Server with MS SQL (follow PMS standard architecture)</p> <p>Magiles HMI/iPC(for WI display) with Vijeo Designer runtime license</p> <p>Auto/Semi-auto process PLC&amp;HMI (M340/M580)</p> <p>Test machine PLC&amp;HMI/PC Programming &amp; Debugging</p> <p>Manual assembly station PLC &amp; HMI configuration &amp; debugging</p> <p>Manual assembly station hardware integration/debugging in PLC (sensor, screwdriver, scanner....)</p> <p>PMS Qualification</p> <p>Technical recipe, Rework Management,</p>	Full	100% Completion

<p>Golden Dummy Sample</p> <p>Standard Manual Assembly Station HMI Template</p> <p>IT-OT Connection- Pick Lights, PLC, Programming, Connected SE Products</p> <p>Cybersecurity Rules</p> <p>PLC Programming, Ladder, SFC, ST, FBD etc.</p>		
<p><b>Additional Knowledge</b></p> <p>All necessary documents (technical specification, BOM, technical data, material</p> <p>Knowledge of relational databases, SQL and ORM technologies (JPA2, Hibernate)</p> <p>MS Visual Studio, ASP.NET</p> <p>Extensive experience with OPC Unified Architecture platform</p> <p>Strong knowledge of communication protocols (Modbus, Ethernet, CAN, Profibus)</p> <p>Strong PLC programming (Control Expert, Machine Expert)</p> <p>Familiar with vision systems (Cognex, Keyence)</p>	Full	100% completion
<p><b>Data Analysis</b></p> <p>AWS/On-Premium Server Details</p>	Partial	

<p>Ensure the CTP CTQs of machines and testers are captured and pushed to cloud/Sever.</p> <p>PY /JD dashboard creation, Traceability tools implementation.</p>		
<p><b>PMS Connections &amp; Enhancements</b></p> <p>PMS Connection with Infra- Laser, Vision Applications, Label Printing Applications, Scanning Systems etc</p> <p>PMS Connection- LDS, MCA, iTAC, SRT etc Eco Applications through API</p> <p>Component Traceability- GS1 Label and Interconnection inside MES</p> <p>Operator Traceability- LDS Versality connection</p>	Partial	
<p><b>Automation Support</b></p> <p>Support MDC Project Automation load – PLC , HMI programming</p> <p>Installation and commissioning of machines</p> <p>Ramup support when needed</p>	Partial	
<p>Qualifications</p>		
<p>REQUIREMENTS</p>		

Education:	Diploma / Bachelors – EEE / EC/ Computers/Mechatronics
Job Related Experience:	8 to 10 Years
Business Understanding:	MES Applications, PLC, Process Automation
Others (e.g. language skills, technical skills):	Read / Write / Speak in English (Required)

Primary Location

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Other Locations

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Function

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Area of focus:OEM - Machine Builder

Additional interest

Additional sub-interest

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Donald

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- Creates an asset-centric architecture (versus PLC-centric or DCS-centric).
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- 

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- Edge [Network](#)

Digital Power solutions to increase energy efficiency

Digital Power solutions help you increase electrical system and assets reliability for your customers, avoid downtime by preventing power failures, and save money by reducing energy use and maintenance. In this chapter you will find introductory courses on the technical characteristics, functions, and applications of key product ranges.

Basic Power Metering

Learn about PowerTag, how to promote it, and how it contributes to the different digital systems in each segment. Learn about PM2000, how to install and program these meters

- Discover PowerTag Energy [Sensors](#)
- EasyLogic [PM2000](#)

Gateways and Energy Servers

The EcoStruxure Panel Server Portfolio Overview provides the trainee with an overview of SE gateways and energy server offers

- EcoStruxure Panel [Server](#)

Power Quality and Power Factor Correction

Gain more knowledge in Power Quality and Power Factor Correction in short videos

- Power Quality and LV Power Factor [Correction](#)
- LV Power Factor Correction [components](#)
- Selection of the right LV [Capacitor](#)

## Protection Relays

This course provides an overview of offer values and ways to address customer pain points

- Easergy [P1](#)

## Sustainability School

Gain sustainability knowledge and skills

### Chapter 1: Gain knowledge

Business and sustainability go hand in hand today. In fact, the survival of our planet depends on it. Sparked by Electricity 4.0 and the rise of electrification and digitalisation, the Schneider Electric Sustainability School is your pathway to in-demand expertise and practical tools. Elevate your brand's reputation and stand apart from the competition. Start with Chapter 1 of Schneider Electric Sustainability school and get a clear understanding of sustainability basics like climate science, scope of impact, and tracking metrics to inform your customers and gain a competitive edge. Chapters 2 and 3 are coming soon.

- Sustainability School Chapter [1](#)

Learn more about mySchneider functionalities

- How to select products and add to [cart](#)
- How to check for products' price and [availability](#)
- How to order [products](#)
- How to order products with generic commercial [references](#)
- How to follow up your [orders](#)
- How to modify [orders](#)
- How to manage orders [notifications](#)

## Partner APIs

- APIs are essential in the digital world to allow a system-to-system collaboration. Your ERP, CRM can reach out directly to our services and get the information [directly](#).

Improve safety & efficiency, maintain & digitize your current system, reduce your carbon footprint & safeguard against disruptions.



Improve safety and efficiency, maintain and digitize your current system, reduce your

carbon footprint and safeguard against disruptions.

Your business continuity relies on the healthy asset management of your electrical and automation systems. You deserve the best industry experts for your safety, resiliency, efficiency and decarbonization.

- For more info, contact our [Consultants](#)

#### EcoConsult Services Portfolio

Be future-ready with EcoConsult to evaluate, map and get actionable insights from your electrical and automation systems!

More safety, resiliency, efficiency & decarbonization.

- Discover more [here](#)

#### EcoConsult Audit

Get actionable insights to improve the safety, resiliency of your assets and systems and to optimize your energy consumption.

- Know [more](#)

#### EcoConsult Electrical Digital Twin

Map your electrical system with EcoConsult Electrical Digital Twin to pave the way to safety, resiliency and digitization journey.

- Know [more](#)

#### EcoConsult System Studies

Help secure your system and equipment design, ensure that your personnel and electrical network are properly protected, and supply availability is maximized.

- Discover [more](#)

#### EcoConsult Design

Enjoy the best-in-class expertise of our design consultant for your installations.

- Learn [more](#)

#### EcoConsult Audit

Start your assessment journey to uncover the hidden efficiencies within your installations. Our Audit Service helps you in the initial assessment of your installation to help ensure your business is continually operating in a safe, resilient and efficient way.

#### EcoConsult Audit for Power

Facility managers operate and maintain complex electrical distribution systems that represent the life blood of their site's operations. EcoConsult audit is a health check of your electrical assets & systems.

- Learn [more](#)

#### EcoConsult Audit for Power Quality

Our consultants provide power quality audits and assessments to improve efficiency, reduce downtime, extend equipment lifespan, and lower carbon emissions to help you initiate your digital transformation. Learn more about the impact of power quality management on electrical system performance in our insightful article.

- Discover more in our [whitepaper](#)

#### EcoConsult Audit for Power Monitoring

Help secure your system and equipment design, ensure that your personnel and electrical network are properly protected, and supply availability is maximized.

- Know [more](#)

#### EcoConsult Audit for Energy Efficiency

Act on short term by reducing your energy consumption and prepare mid term towards Net Zero footprint trajectory with the help our consultants

- Learn [more](#)

#### EcoConsult Audit for Industrial Automation

Industrial manufacturing plants faces continuous challenges related to the most critical assets driving production. This consulting services starts with a lifecycle analysis of industrial automation assets and delivers recommendations to mitigate risks to plant reliability. Additionally, it aids in establishing a plan for plant modernization. For more info, download the brochure

- Learn [more](#)
- [Brochure](#)

#### EcoConsult Audit for Data Center

A consultative offer that combines product know-how and domain expertise to provide targeted solutions for the data center including critical power and cooling as well as MV and LV equipment.

- Contact our [Consultants](#)

#### EcoConsult Electrical Digital Twin

Get the support of our expert consultants on the Electrical Digital Twin Service to execute the digital transformation of your single-line diagram with leading ETAP software and execute relevant power system studies. With our service plan, we help you maintain your power engineering plant architecture and visualize your ac / dc electrical distribution from HV to LV.

- Request a [demo](#)

#### EcoConsult System Studies

We offer a large range of Power System Analysis, including short circuit analysis, protection coordination studies, arc-flash study, load shedding lightning protection, grid connection, load flow, harmonics, energy compensation and dynamic stability.

- Contact our [Consultants](#)

#### Short Circuit Analysis

- Tables comparing short circuit levels to the rating of the equipment
- Computer-generated single-line diagram of the power distribution system
- Recommendations for improvements on underrated equipment
- Contact our [Consultants](#)

#### Protection Coordination Study

- Improving uptime by reviewing protection scheme and make upgrades recommendations if needed
- List of protection devices, including relays, fuses, circuit breakers, and the equipment to which they apply
- Suggested settings for adjustable devices
- Time-current curves (TCC) illustrating the resulting protection and system coordination
- Contact our [Consultants](#)

## Arc Flash Study

- Help improve safety by assessing the arc-flash incident energy and recommend operators protective equipment(PPE)
- Equipment-specific labels
- Recommendations for equipment modernization
- Recommendations for mitigation of arc-flash hazards
- Discover [more](#)

## Other Studies

We also provide Consulting Services in the following areas, Motor starting, Load flow, Harmonics, Electrodynamics stability,

- Contact our [Consultants](#)

## Product Selector Tool

This tool is designed to assist you through the product selection process.

## Try our Product Selector

[Content Training Installed Base Programs](#)

---

### Overview All Projects

Project Builder

Active Projects Archived Projects Shared with me  
Project-15 Untitled

Last Modified: 19/11/2024

open

Engineering

Date: 19/11/2024

End User Company: Tshingombe engineering

Project Owner: Tshingombe fiston

Project-14 Untitled

Last Modified: 25/6/2024

open

Date: 25/6/2024

End User Company: Tshingombe engineering

Project Owner: Tshingombe fiston

Project-13 Untitled

Last Modified: 23/4/2024

open

engineering scie

Date: 23/4/2024

End User Company: Tshingombe engineering

Project Owner: Tshingombe fiston

Project-12 Untitled

Last Modified: 17/1/2024

open

undefined frame work implentation system logic control

Date: 15/1/2024

End User Company: Tshingombe engineering

Project Owner: Tshingombe fiston

R 119 344,00

Project-11 Untitled

Last Modified: 15/1/2024

open

undefined

Date: 15/1/2024

End User Company: Tshingombe engineering

Project Owner: Tshingombe fiston

R 15 985,00

Project-10 Untitled

Last Modified: 15/1/2024

open

undefined

Date: 15/1/2024

End User Company: Tshingombe engineering

Project Owner: Tshingombe fiston

R 15 985,00

Project-9 Untitled

Last Modified: 14/1/2024

open

Date: 14/1/2024

End User Company: Tshingombe engineering

Project Owner: Tshingombe fiston

Project-6 Untitled

Last Modified: 14/1/2024

open

Engineering electrical analyse design investigation .implentation system assessment  
police .security industrial.

Date: 14/1/2024

End User Company: Tshingombe engineering

Project Owner: Tshingombe fiston

Project-7 Untitled

Last Modified: 14/1/2024

open

Date: 14/1/2024

End User Company: Tshingombe engineering

Project Owner: Tshingombe fiston

Project-5 Untitled

Last Modified: 12/1/2024

open

undefined

Date: 12/1/2024

End User Company: Tshingombe engineering

Project Owner: Tshingombe fiston

Project-4 Untitled

Last Modified: 12/1/2024

open

Date: 12/1/2024

End User Company: Tshingombe engineering

Project Owner: Tshingombe fiston

Project-3 Untitled

Last Modified: 12/1/2024

open

undefined

Date: 12/1/2024

End User Company: Tshingombe engineering

Project Owner: Tshingombe fiston

R 23 325,59

Project-2 Untitled

Last Modified: 12/1/2024

open

undefined

Date: 12/1/2024

End User Company: Tshingombe engineering

Project Owner: Tshingombe fiston

R 12 370,38

Project-1 Untitled

Last Modified: 11/1/2024

open

Date: 11/1/2024

End User Company: Tshingombe engineering

Project Owner: Tshingombe fiston

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- 
- Privacy Policy
- [Cookie Notice](#)
- Change your cookie settings

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mySchneider

My Preferences

Tshingombe fiston  
PRM

Print QRCode

- Settings

Time Zone:

Time Zone:

Display Language

Display Language

(User will be required to log out, and log back into the portal upon “Save” to refresh the language pack.)

Select Signature

Select Signature

☒

Opt out of Shopping Cart Notifications

(Click the checkbox if you would like to unsubscribe from Sh

[Skip to main content](#)

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[Show Navigation Menu](#)

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Main content below

Tshingombe fiston

- Bio
- Transcript
- Actions

- Home
- Tshingombe fiston
- My Courses: Tshingombe fiston

My Courses: Tshingombe fiston

Use the transcript to manage all active training.

0 HRS

AGGREGATE TRAINING COMPLETED

FISCAL YEAR ENDING

12/31/2025

COST

R0.00

Filter by Training Status

[Active](#)

Sort by

[Date Added](#)

Filter by Training Type

[All Types](#)

Search by Keyword

Search

Search Results (134)

- EcoXpert Smart Grid, Technical, Intermediate: Geographic Information Systems Path  
Due : No Due Date Status : In Progress Training Type : Curriculum Training Status : Active
- 
- Basic Machines with PacDrive 3 [VILT] (Test)  
Due : No Due Date Status : Failed Training Type : Test Training Status : Active
- 
- Cybersecurity für Schneider Electric Service Partner / Cybersecurity for Schneider

## Electric Services Partners (German)

Due : No Due Date Status : In Progress Training Type : Online Class Training Status : Active

- 
- EBO 2023: Engineering EasyLogic

Due : No Due Date Status : In Progress Training Type : Curriculum Training Status : Active

- 
- Service for Lexium [VILT] (Test)

Due : No Due Date Status : Failed Training Type : Test Training Status : Active

- 
- 20 Mobile Terms You Probably Know

Due : No Due Date Status : In Progress Training Type : Curriculum Training Status : Active

- 
- Schneider Home Certification

Due : No Due Date Status : Registered Training Type : Curriculum Training Status : Active

- 
- EBO 2022: Engineering EBO

Due : No Due Date Status : In Progress Training Type : Curriculum Training Status : Active

- 
- EBO 2023: Engineering EBO

Due : No Due Date Status : In Progress Training Type : Curriculum Training Status : Active

- 
- EBO 2024: Engineering EBO

Due : No Due Date Status : In Progress Training Type : Curriculum Training Status : Active

- 
- EBO 2022: Value Based Selling

Due : No Due Date Status : In Progress Training Type : Curriculum Training Status : Active

- 
- DIN Ethernet Technical Overview

Due : No Due Date Status : In Progress Training Type : Online Class Training Status : Active

- 
- Applying OWASP 2017 Mitigations Series

Due : No Due Date Status : In Progress Training Type : Curriculum Training Status : Active

- 
- EcoStruxure Power Foundational 2.0

Due : No Due Date Status : In Progress Training Type : Online Class Training Status : Active

- 
- Fundamentals of Threat Modeling

Due : No Due Date Status : In Progress Training Type : Online Class Training Status :

Active

- 

- Sustainability School for Partners Chapter 2

Due : No Due Date Status : In Progress Training Type : Curriculum Training Status : Active

- 

- Basic Machines with PacDrive 3 (Test)

Due : No Due Date Status : Failed Training Type : Test Training Status : Active

- 

- EcoStruxure Building Technical Training For EcoXperts 2023 - Proficient

Due : No Due Date Status : In Progress Training Type : Curriculum Training Status : Active

- 

- Introduction to EcoCare : Next Generation Services Membership

Due : No Due Date Status : Registered Training Type : Online Class Training Status : Active

- 

- Escola de Sustentabilidade para Parceiros. Capítulo 1/Sustainability School for Partners. Chapter 1 (Portuguese)

Due : No Due Date Status : In Progress Training Type : Curriculum Training Status : Active

- 

- Motion Block : Part I (Test)

Due : No Due Date Status : Failed Training Type : Test Training Status : Active

- 

- Transformers and motor applications in industries

Due : No Due Date Status : In Progress Training Type : Curriculum Training Status : Active

- 

- EBO 2023: Engineering Upgrade

Due : No Due Date Status : In Progress Training Type : Curriculum Training Status : Active

- 

- PowerLogic P5: Protection Engineering

Due : No Due Date Status : In Progress Training Type : Curriculum Training Status : Active

- 

- EVlink ProAC Calibration Law Compliant Basic (German)

Due : No Due Date Status : Registered Training Type : Online Class Training Status : Active

- 

- 1
- 2
- 3
- 4
- 5
- Next
- Last

1 to 25 of 134

Version: 17.3.0.171

EcoXpert Smart Grid, Technical, Intermediate: Geographic Information Systems Path

## Options

### [Section 1: Overview of the ArcFM XI Series Solution](#)

»

100%

### [ArcFM XI Series Applications Whirlwind Tour](#)

Completed : 0 Min Required : 0 Total Items : 3

- 

#### [ArcFM](#)

#### [Designer XI Whirlwind Tour](#)

Status : Registered

Due : No Due Date

Training Hours : 1 hrs

Designer XI is part of the ArcFM XI Series Solutions, which assists you in keeping accurate data, working quickly and efficiently, and making sure that data can...

- 

- 

ArcFM  
Editor XI

Whirlwind  
Tour

Status : Not  
Activated

Due : No  
Due Date  
Training  
Hours : 1 hrs

This 1-hour  
video  
introduces  
major ArcFM  
Editor XI  
concepts  
and  
functionality.  
The video  
shows how  
ArcFM  
Editor XI  
extends  
ArcGIS Pro  
and provides  
specific...

- 

- 

ArcFM Fiber  
XI  
Whirlwind  
Tour

Status : Not  
Activated  
Due : No

Due Date  
Training  
Hours : 40  
min

ArcFM Fiber  
Manager XI  
focuses on  
simplifying  
the  
creation,  
editing,  
analysis,  
and  
visualization  
of complex  
fiber optic  
equipment  
hierarchies  
and...

- 

Test - Basic Machines with PacDrive 3 [VILT] (Test)

Machine Solutions: Basic Machines PacDrive 3 VILT (Test)

---

Question 1 of 15.

By Cycle Time 10ms InitModuleAction will be worked up to

- ☐ immediately
  - ☐ 9.999 ms after i\_xEnable is given
  - ☐ 19.999 ms after i\_xEnable is given
  - ☐ 10 ms after i\_xEnable is given
  - ☐ Mark for follow up
- 

Question 2 of 15.

Variables marked as "VAR PERSISTENT RETAIN" will keep their current value after a "reset cold"

True   False

☐☐

☐ Mark for follow up

---

Question 3 of 15.

If the identification mode of Sercos devices is set to "Topological address" ....

- ☐ a replaced drive must be configured manually
  - ☐ the network cables on the new device must be connected in the way as the replaced device
  - ☐ no manual configuration is necessary if a device is replaced
  - ☐ Firmware version in the new device must be the same as in the replaced device
  - ☐ Mark for follow up
-

Question 4 of 15.

In which SERCOS Phase the electronic Type Plate from Encoder will be read out?

☐

1

☐

2

☐

3

☐

4

☐

Mark for follow up

---

Question 5 of 15.

How to calculate maximum allowed Continuous Current

☐

Continuous Torque \* TorqueConstant

☐

Continuous Torque / TorqueConstant

☐

TorqueConstant / Continuous Torque

☐

Mark for follow up

---

Question 6 of 15.

What is the meaning of AxisState = 3

☐

The drive is in position control, but brake is not open

☐

Drive has full torque and waits for master job.

☐

Drive follows Master Job (Motion)

☐

Mark for follow up

---

Question 7 of 15.

In which Library we can find 'FB\_DriveEnable' ?

- ☐ Standard Library
  - ☐ PacDrive Library
  - ☐ AxisModule Library
  - ☐ Template Library
  - ☐ Mark for follow up
- 

Question 8 of 15.

If FB\_VarioPosJerk is used in positioning mode "Relative"

- ☐ the position counter is set to zero before positioning, then it is positioned to the specified value in i\_LrTarget
  - ☐ the position counter is not influenced before positioning.
  - ☐ the position counter will be reset to 0 after successful positioning
  - ☐ Mark for follow up
- 

Question 9 of 15.

What parameters you get automatically changed by change of Parameter 'FeedConstant'?

- ☐ MaxVel
  - ☐ UserMaxVel
  - ☐ MaxAcc
  - ☐ TrackingDeviationLimit
  - ☐ Mark for follow up
- 

Question 10 of 15.

Bleeder is a

- ☐ Braking Resistor
  - ☐ Leakage Current
  - ☐ FeedForward Current
  - ☐ Mark for follow up
- 

Question 11 of 15.

Which statement is valid for 'TrackingDeviationLimit" parameter of a Lexium 62 drive?

- ☐ If the maximum tracking deviation is exceeded a diagnostic message with diagnostic class 2 or 3 is triggered
  - ☐ If the maximum tracking deviation is exceeded a diagnostic message with diagnostic class 3 is triggered
  - ☐ If the tracking deviation value is exceeded by a factor of eight, a diagnostic message of class 3 is triggered
  - ☐ is calculated by 'RefMechPosition' - 'MechPosition'
  - ☐ is calculated by 'RefPosition' - 'Position'
  - ☐ Mark for follow up
- 

Question 12 of 15.

Desired Velocity = 100U/s, GearIn = 25, GearOut = 100. With what Velocity the Motor shaft turns ?

- ☐ 25 U/s
  - ☐ 100 U/s
  - ☐ 400 U/s
  - ☐ Mark for follow up
-

Question 13 of 15.

Jerk is

- ☐  $dAcc / dt$
  - ☐  $dAcc \text{ max} / dAcc \text{ min}$
  - ☐ stopping way by given Acceleration
  - ☐ Mark for follow up
- 

Question 14 of 15.

With what parameter we can reduce Torque ?

- ☐ TorqueConstant
  - ☐ UserCurrentLimit
  - ☐ LimitCurrent
  - ☐ Mark for follow up
- 

Question 15 of 15.

In 'Motor' Folder you can find parameters 'NominalSpeed' and 'MaxSpeed'. If you run FB\_EndlessFeed you can run Axis with

- ☐ Value of 'NominalSpeed'
  - ☐ Value of 'MaxSpeed'
  - ☐ Mark for follow up
- 

Test Results - Tshingombe fiston

Questions on Test: 15

Questions Correct: 5

Questions Incorrect: 10

Percent Correct: 33%

Passing Score: 70%

Pass/Fail: Failed

Review Test: [Review](#)

#### Scores By Section

Machine 33% (5 Out Of 15)

Solutions:

Basic

Machines

PacDrive 3

VILT (Test):

Overall 33% (5 Out Of 15)

Score:

Cybersecurity Training für Schneider Electric Service Partner

KURS STARTEN [DETAILS](#)

#### Description

Die Marke Schneider Electric wird gegenüber unseren Kunden, Aktionären und unseren Mitarbeitern durch das Verhalten Dritter vertreten, die mit der Durchführung von Arbeiten oder Dienstleistungen in unserem Namen oder unter einem autorisierten Dienstleistungspartnerausweis.

Im kommenden Kurs "Cybersecurity für Schneider Electric Service Partner", werden Sie:

Die wichtigsten Gefahren verstehen  
Die Gebote und Verbote lernen, um Ihre Kunden- und Unternehmensumgebung und -daten zu schützen

---

#### Curriculum

## EBO 2023: Engineering EasyLogic

### Last Updated

07/10/2024

### Duration

18 hours, 56 minutes

### Details

This Curriculum is intended for engineering and service personnel working with the EcoStruxure Building system and EcoStruxure Building Operation 2023 software.

- The participants will identify recommended architecture for EasyLogic range and Fieldbus levels, including how individual hardware and software components are incorporated into the system.
- The participants will learn all EasyLogic range Controllers Features and limitations for new and retrofit projects
- The participants will learn the process for bringing online EasyLogic range controllers, MP-x, RP-C, RP-IO, SP90, and EasyLogic Living sensors, in a BACnet environment, as well as the basics of implementing BACnet engineering techniques.

### Note!

Recommended Pre-requisite are:

EBO 2023: Engineering Upgrade – Curriculum ID: BLDECXCS0001029 Or

EBO 2023: Engineering EBO – Curriculum ID: BLDECXCS0001030

Course Code: BLDECXCS0001022

### Provider

Digital Building Academy

### Version

4.0

### Available Language(s)

English (US)

### Subject(s)

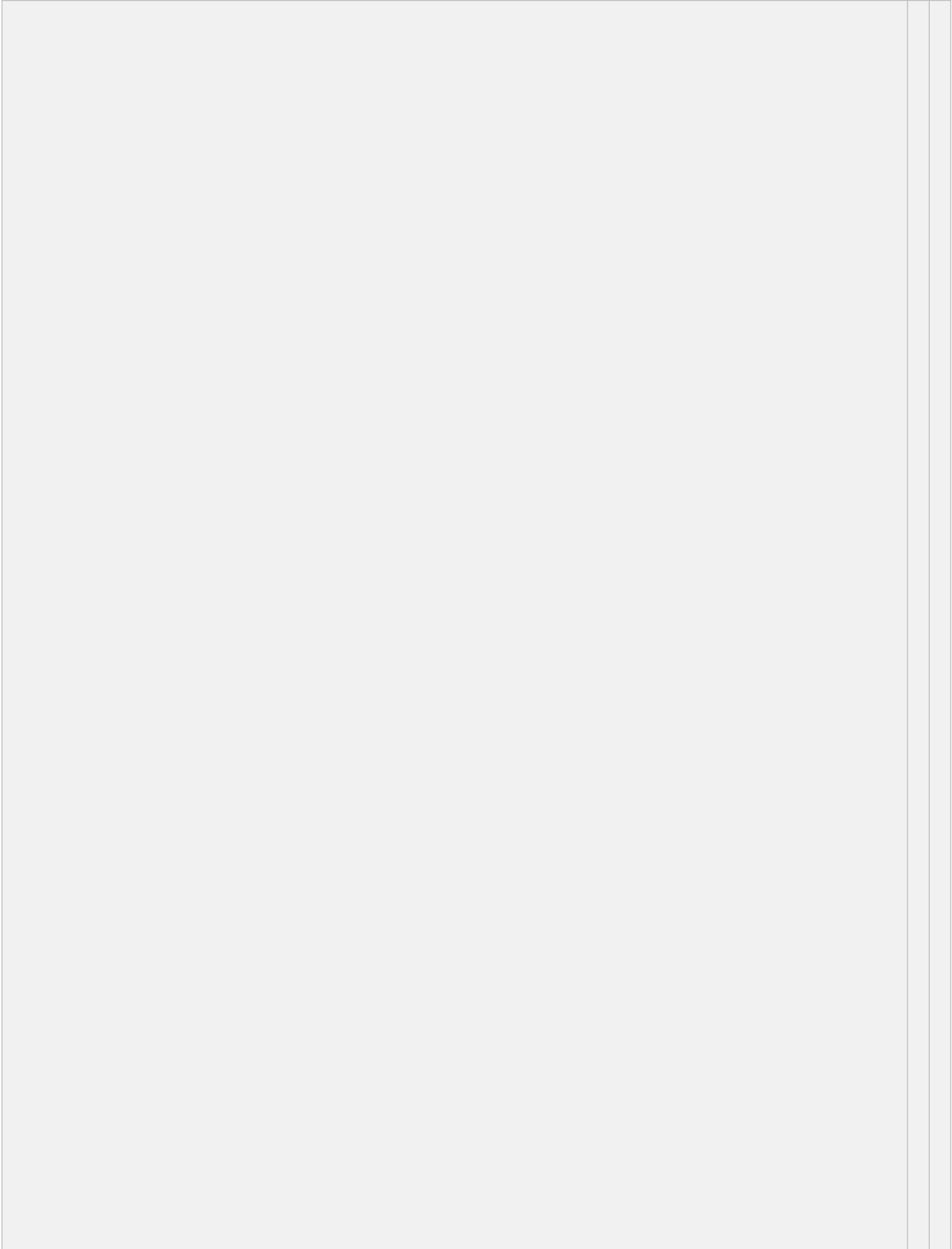
EcoStruxure for Building

### Contents

7 Trainings

On-Line Course

- Online ClassEBO 2023: EIA 485 Electrical and Physical Characteristics
- TestEBO 2023: EIA 485 Electrical and Physical Characteristics (Test)
- Online ClassEBO 2023: BACnet MS/TP



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Active Training: Tshingombe fiston

Title	Type	Due Date	Score	Status
EcoXpert Smart Grid, Technical, Intermediate: Geographic Information Systems Path	Curriculum	None		In Progress
Basic Machines with PacDrive 3 [VILT] (Test)	Test	None	33	Failed
Cybersecurity für Schneider Electric Service Partner / Cybersecurity for Schneider Electric Services Partners (German)	Online Class	None		In Progress
EBO 2023: Engineering EasyLogic	Curriculum	None		In Progress
Service for Lexium [VILT] (Test)	Test	None	33	Failed
20 Mobile Terms You Probably Know	Curriculum	None		In Progress
Schneider Home Certification	Curriculum	None		Registered
EBO 2022: Engineering EBO	Curriculum	None		In Progress
EBO 2023: Engineering EBO	Curriculum	None		In Progress
EBO 2024: Engineering EBO	Curriculum	None		In Progress
EBO 2022: Value Based Selling	Curriculum	None		In Progress
DIN Ethernet Technical Overview	Online Class	None		In Progress
Applying OWASP 2017 Mitigations Series	Curriculum	None		In Progress
EcoStruxure Power Foundational 2.0	Online Class	None		In Progress
Fundamentals of Threat Modeling	Online Class	None		In Progress
Sustainability School for Partners Chapter 2	Curriculum	None		In Progress
Basic Machines with PacDrive 3 (Test)	Test	None	20	Failed
EcoStruxure Building Technical Training For EcoXperts 2023 - Proficient	Curriculum	None		In Progress

Introduction to EcoCare : Next Generation Services Membership	Online Class	None	Registered
Escola de Sustentabilidade para Parceiros. Capítulo 1/Sustainability School for Partners. Chapter 1 (Portuguese)	Curriculum	None	In Progress
Motion Block : Part I (Test)	Test	None10	Failed
Transformers and motor applications in industries	Curriculum	None	In Progress
EBO 2023: Engineering Upgrade	Curriculum	None	In Progress
PowerLogic P5: Protection Engineering	Curriculum	None	In Progress
EVlink ProAC Calibration Law Compliant Basic (German)	Online Class	None	Registered
EcoStruxure Building: Graphics Editor Intermediate	Online Class	None	In Progress
Electrical Arc Flash Awareness	Online Class	None	In Progress
EcoStruxure Panel Server: Architectures around Panel Server	Online Class	None	Registered
Sustainability School for Partners Chapter 1	Curriculum	None	In Progress
Understanding the cash flow statement	Online Class	None50	In Progress
Personal Protective Equipment Overview	Online Class	None	Registered
Building Controls II: Control Sensors	Online Class	None	Registered
EcoStruxure Building: Prescription - Mechanical & Control - Part 1 - HVAC Basics	Curriculum	None	In Progress
Masterpact M auf Masterpact MTZ - Modernisierung mit ECOFITTM/ Masterpact M to Masterpact MTZ upgrade solutions with ECOFITTM (German)	Online Class	None	In Progress
Be S.A.F.E. First	Online Class	None	In Progress

EVlink ProAC Calibration Law Compliant Basic (German)	Online Class	None0	In Progress
KNX Basic Certification Blended	Curriculum	None	In Progress
Introduction à EcoStruxure Grid: Foundational/Introduction to EcoStruxure Grid: Foundational (French)	Online Class	None0	In Progress
PowerLogic: Technical Overview	Curriculum	None	In Progress
Testes Altivar Technique	Curriculum	None	In Progress
Advanced Power Metering: PowerLogic ION9000 Technical Overview: Part 1	Online Class	None	In Progress
Robotics (Test)	Test	None44	Failed
Social Selling (Season 1) - SEIQ	Material	None	In Progress
Understanding Software Licensing	Online Class	None40	In Progress
Drives: Fundamentals of Kinematics: Part 2 of 2	Video	None	Pending Prerequisite
LayoutFAST: General Overview	Online Class	None	In Progress
Motion Block Basics	Online Class	None	In Progress
Material Working Machinery: Discover the Machines	Online Class	None20	In Progress
Drives: Fundamentals of Kinematics: Calculation Downhill Conveyor	Video	None	Registered
Field Services Operations : BCEC BCWC TurboCor for FSR Test	Test	None28	In Progress
Motor Starters with Contactors	Curriculum	None	In Progress
Discover the Hotels Market	Online Class	None	In Progress
Correntes de curto-circuito/Short-Circuit Currents (Portuguese)	Online Class	None0	In Progress

EcoStruxure Building: Graphics Editor Advanced	Online Class	None	In Progress
EBO 2023: EIA 485 Electrical and Physical Characteristics	Online Class	None0	In Progress
Active Harmonic Filter: HMI Screens (PowerLogic™ AccuSine PCSP & PCSn)	Video	None	Registered
Altivar Drives: Braking Function (Test)	Test	None25	Failed
Escolha da área da seção transversal do cabo/Choice of Cable Cross-Section Area (Portuguese)	Online Class	None0	In Progress
EcoStruxure Plant: Safety	Video	None	Registered
Module 1: Battery Basics	Online Class	None	In Progress
Foundations of Data Center Physical Infrastructure Management	Online Class	None10	In Progress
Test: Physical Infrastructure Management Basics Quiz	Test	None30	Failed
Easy Lexium 16 Servo Drives & BCH Servo Motors (English) / Servoaccionamientos Easy Lexium 16 y servomotores BCH (Spanish)	Online Class	None	In Progress
Physical Infrastructure in IT Network	Curriculum	None	Exception Requested
An Introduction to Life Sciences (Test)	Test	None30	Failed
An Introduction to Life Sciences	Video	None	Registered
The Convergence of IT/OT: 2- The Impact of the Digital Transformation	Online Class	None0	In Progress
Altivar Machine Professional	Curriculum	None	In Progress
Compreendendo a compatibilidade eletromagnética/Understanding Electromagnetic Compatibility (Portuguese)	Online Class	None0	In Progress
Drives Basics: Electromagnetic Compatibility (EMC)	Online Class	None0	In Progress
ELECTRICAL SAFETY IN THE WORKPLACE For non-	Online	None	In Progress

electrical staff	Class			
Electronic VAR Compensation : Technical Overview – HMI Screens PowerLogic™ AccuSine EVC+)	Video	None	Registered	
Notions de base sur l'électricité : électrons en mouvement / Electricity Basics: Moving Electrons (French)	Online Class	None	In Progress	
Energy Server Com'X 510: Technical Overview	Online Class	None	In Progress	
Drives: Fundamentals of Kinematics : Part 1 of 2	Video	None	Registered	
Industrial Edge for the WWW Industry Part 1	Video	None	Registered	
Industrial Management	Online Class	None	In Progress	
Power Quality and Power Advisor Summary	Video	None	Registered	
Regulations & Regulatory Guidance in Life Sciences (Test)	Test	None10	Failed	
Retrofit Power Metering: PowerLogic BCPM Technical Overview	Online Class	None	In Progress	
Power Meters: Meters Positioning Initiative #1	Video	None	Registered	
Power and Energy Meters	Video	None	Registered	
New Easy UPS On-Line Lithium-ion 1-3kVA & NMC, established Easy UPS, Easy Racks & PDUs	Video	None	Registered	
Surveillance et alerte de la distribution électrique /EcoStruxure Power: Electrical Distribution Monitoring & Alarming (French)	Online Class	None	In Progress	
Introdução ao projeto de distribuição de baixa tensão/Introduction to Low Voltage Distribution Design (Portuguese)	Online Class	None	In Progress	
Discover Motor Control: Part 2: Branch Circuit I	Online Class	None	In Progress	
Innovation Talk: Basics of RFID Sensors for Controlling Access & Tracking:Telemecanique Sensors	Video	None	Registered	
IDPE Section 4: Molded Case Circuit Breakers (Test)	Test	None11	Failed	

Test ProDiag Breaker for Field Services Representative (FSR)	Test	None67	Failed
Design Canalis with CanCAD : Project execution checklist Part 3	Online Class	None20	In Progress
Design Canalis with CanCAD : Conclusion Part 7	Online Class	None13	In Progress
Altivar Soft Starter: ATS22 Mounting and Cabling	Video	None	Registered
Altivar Machine: ATV340: Mounting and Cabling: Part 3 of 4	Video	None	Pending Prerequisite
Altivar ATV12 Mounting and Cabling: Part 1	Video	None	Registered
Design Canalis with CanCAD : Launch CanCAD and introduction Part 2	Online Class	None20	In Progress
Altivar Process: Mounting and Cabling: Floorstanding: Part 2 of 2	Video	None	Pending Prerequisite
Altivar Machine: ATV340: Mounting and Cabling: Part 4 of 4	Video	None	Pending Prerequisite
EcoStruxure Security Expert: ESMI Transition Post Transition, Part 4 of 4	Video	None	Registered
Introduction to Transformer Protection Basics	Online Class	None0	In Progress
Masterpact MTZ for Services Representative (SR)	Test	None24	Failed
EcoStruxure Security Expert: An introduction to EcoStruxure Security Expert	Video	None	Registered
EcoStruxure Security Expert: INET to Security Expert Transition (Test)	Test	None40	Failed
EcoStruxure Security Expert: ESMI – Security Expert - transitio: Tietokannan muunnos Esmikosta Security Experttiin, Osa 3/4	Video	None	Registered
Discover High Impedance Busbar Protection	Online Class	None0	In Progress
Discover Advanced Distance Protection	Online Class	None0	In Progress

Introduction to Distance Protection	Online Class	None0	In Progress
Discover Low Impedance Busbar Protection	Online Class	None0	In Progress
Discover Basic Line Differential Protection	Online Class	None0	In Progress
Discover the basic arc protection principles and offers	Online Class	None0	In Progress
Discover Advanced Command and Control Features	Online Class	None0	In Progress
Discover Basic Command and Control Features	Online Class	None0	In Progress
EcoXpert Substation Automation, Proficient, Decentralized Architecture	Curriculum	None	In Progress
Motor Protection: Part 3: Coordination in Motor Starters	Online Class	None	In Progress
Motor Protection: Part 2: Motor Protection	Online Class	None	In Progress
Discover Basic Generator Protection	Online Class	None0	In Progress
Discover Advanced Generator Protection	Online Class	None0	In Progress
Deliver Switchboard Project Digitally: Episode 1	Video	None	Registered
EcoXpert Smart Grid, Technical, Intermediate: Grid Operation Solution Path	Curriculum	None	In Progress
EcoXpert Smart Grid, Sales, Proficient: Grid Operations Solution (test)	Test	None30	Failed
Tesys T drawer wiring with Ethernet 1	Video	None	Registered
EcoStruxure Building: MP-x Power Wiring	Video	None	Registered
Discover Square D wiring devices: X series and XD series	Online Class	None0	In Progress

EBO 2022: Advanced Engineering	Curriculum	None	In Progress
EcoStruxure Power Automation System Engineering video tutorial – Electrical Design Overview	Video	None	Registered
EcoStruxure Building: Value Based Selling 3.x	Curriculum	None	In Progress
Privacy by Design 2.0	Video	None	Registered
A Semi-Serious Internet Terminology and Slang	Curriculum	None	In Progress
Discover the Single unified experience in HVAC	Video	None	Registered
Maximize Profitability and Operations Efficiency 3/3	Video	None	Registered
Academy Virtual Training (SE South Africa)	Video	None	Registered
EBO 2023: Engineering EBO Certification (Test)	Test	None42	Failed
EBO 2022: Installation of EcoStruxure Building Operation (Test)	Test	None40	In Progress
Digital services & robotics in CPG packaging for Greater efficiency	Video	None	Registered
Advanced Electrical Safety	Curriculum	None	

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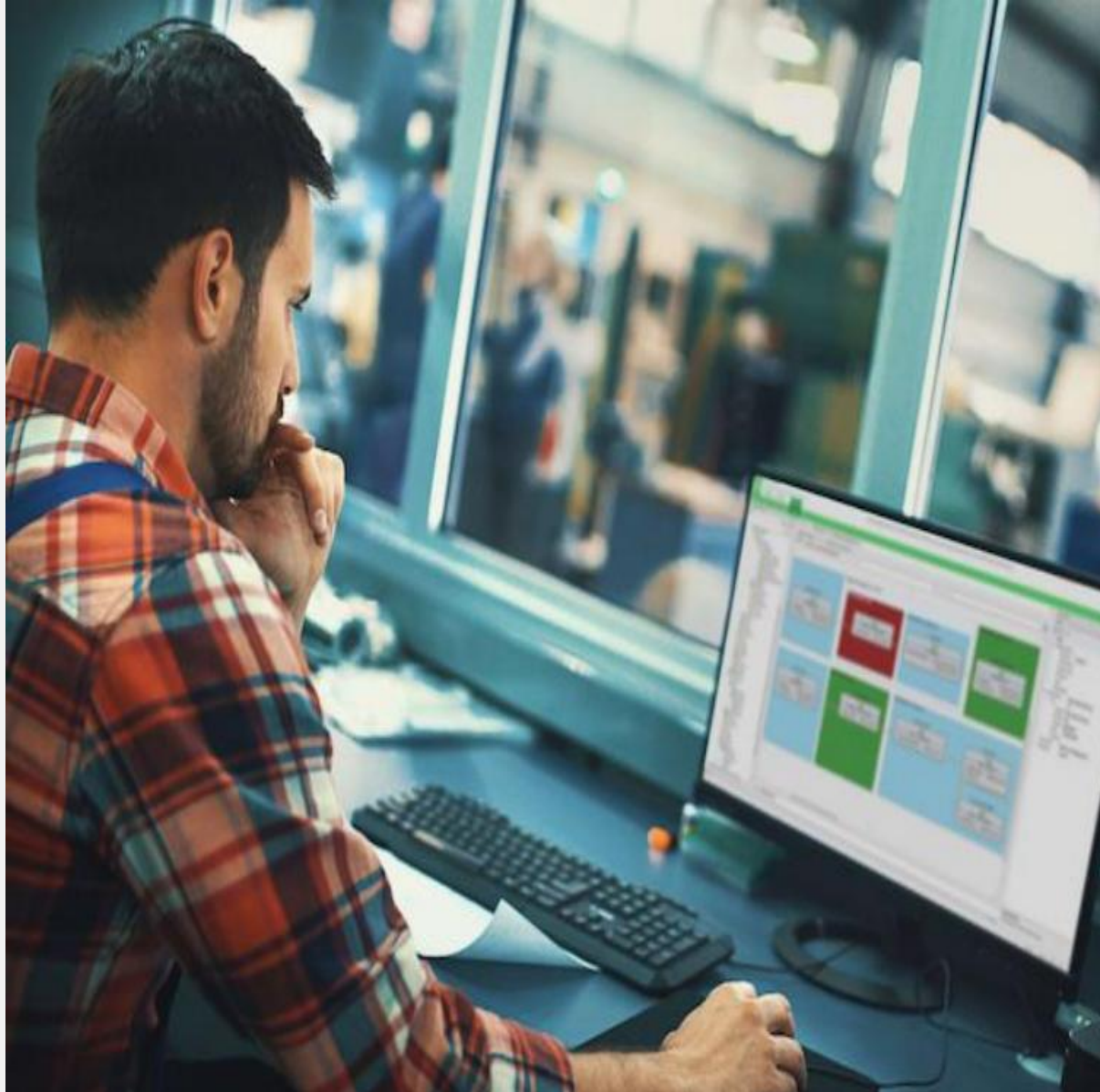
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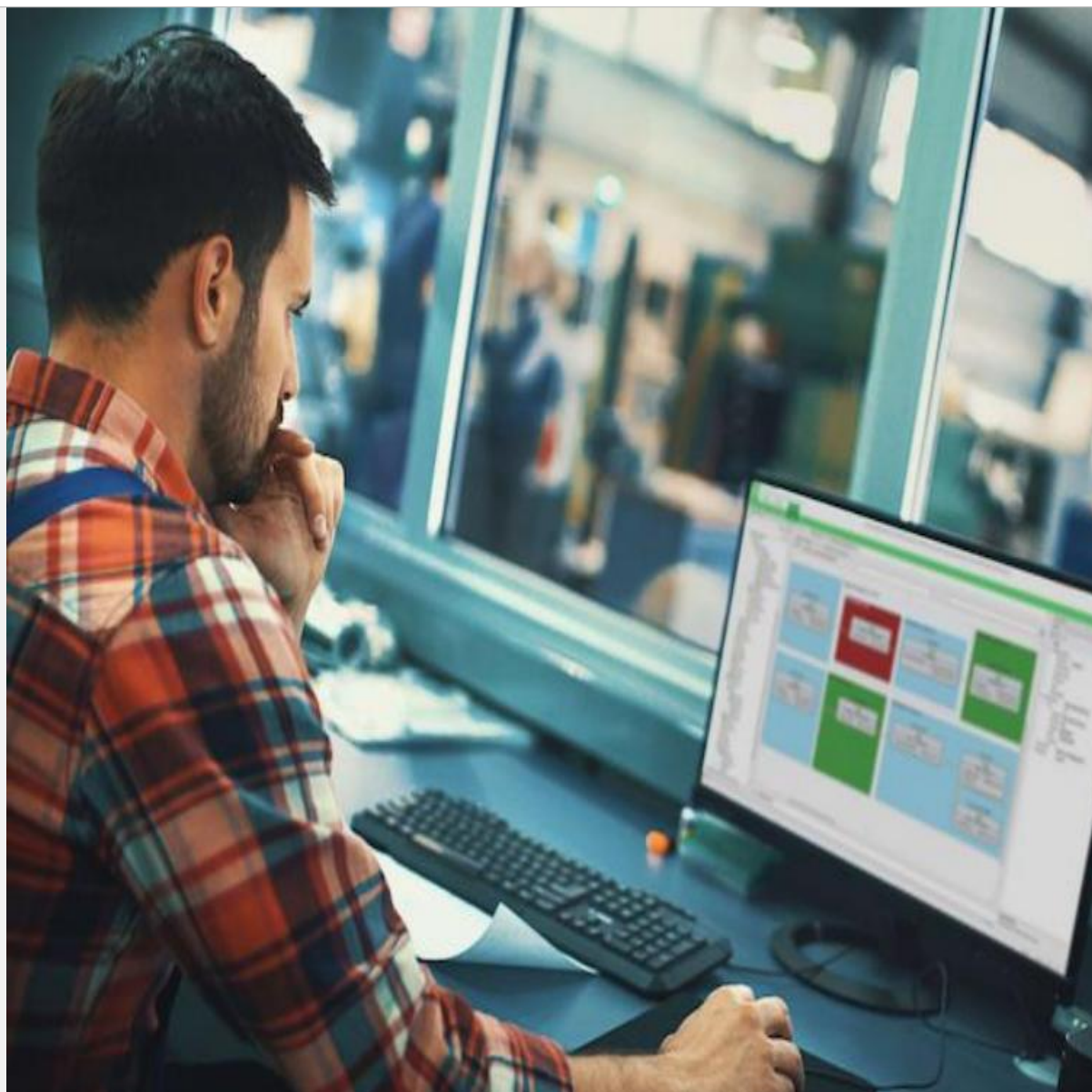
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Project-13 Untitled

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30 In Progress

6 Registered

Training Offers

completed

10

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Sustainability School: Training you for success

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Turn your climate ambition into action



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In our FUNDAMENTAL and ADVANCED Chapter 1 courses, discover why the low-carbon

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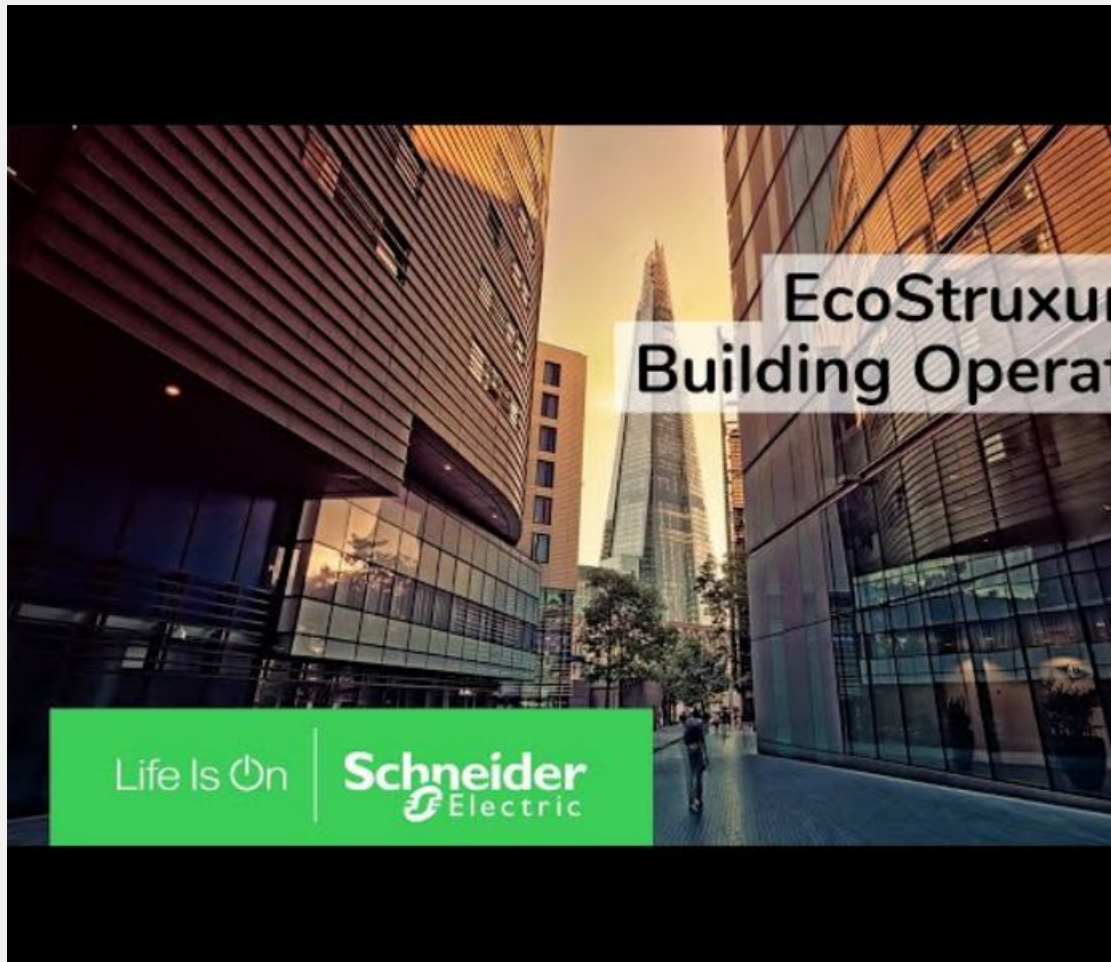
Learn how you can turn your sustainability knowledge into business opportunities, using our tools to launch a decarbonization strategy and action plan for you and your customers.

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- Turn system data into actionable insights

EcoStruxure Building Operation is an open and scalable software platform providing insight, control and management of multiple building systems and devices in one mobile-enabled convenient view. It delivers valuable data for decision-making to improve energy management and increase efficiency for better building performance and comfort, reduced carbon, and more sustainable building environments.

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Benefits of EcoStruxure Building Operation Software

## Flexibility

Modular and scalable architecture with customisable, persona-based views of buildings of any size or complexity. Mobile-ready and accessible on PC, tablet, or smartphone to ensure efficiency.

## Open integration

Tested, interoperable integration of multiple systems from inside and outside the building, native support of standard protocols and MQTT, and seamless access to third-party tools.

## Simple to upgrade

Upgrade and expand on your terms – over time or at once with multi-version support – with continuous access to the latest version through subscription-based software assurance.

## Cybersecurity

Reduced cyber threat risk with a Secure Development Lifecycle (SDLV2) policy, advanced encryption and authentication, and built-in protection against software alterations.

## Features

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Further explore EcoStruxure Building Operation Software

- Supervision and management
- Engineering tools
- Specialised integrations

#### Data capturing

Designed for buildings of any size, the Enterprise Server not only collects building data, but also configures, controls, and monitors the entire system. With Enterprise Central, a supervisory server for up to 50 integrated Enterprise Servers and hosting up to 2,500 automation servers, you can easily scale operations management across the largest enterprise from a single location.

- Learn more about Enterprise [Central opens in new window](#)
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#### Collect data

Created with accessibility and user experience in mind, WebStation and WorkStation allow users to view and manage data with state-of-the-art graphics, alarms, scheduling, trend logs and reports. In addition to building operations insights, WebStation provides an optimised mobile experience, enabling convenient access to building data at any time and place without additional software installations.

- Learn more about [WebStation opens in new window](#)
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#### EcoStruxure Building Commission

This mobile app increases project speed with flexible, ladder-free commissioning of controllers, and eliminates dependencies on network infrastructure.

#### Project Configuration Tool

This offline engineering platform enables engineers to spend less time at customer sites.

Design, programme, model and analyse solutions in a virtual environment without the need for hardware.

#### Automated Engineering Tool

This cloud-based tool drives efficiency and standardisation with a large selection of tried-and-true standard HVAC applications and components.

#### Modernised Programming

This visual object-orientated system streamlines programming, lowers personnel requirements and project costs while keeping maintaining customizability.

#### Regulated Industries Compliance Pack

Get facility-wide accountability and traceability of environmental and security conditions that can impact the quality and safety of controlled environments. Comply with FDA 21 CFR Part 11 and ALCOA principals.

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#### EcoStruxure Power Monitoring Expert

Only Schneider Electric integrates building and power management in a single view. Our power management software ensures electrical network health, increases power quality awareness, and improves energy usage accountability.

- Learn [more](#)

#### EcoStruxure Smart Connector

An open-source developer framework, including SDK, for linking third-party systems to create innovative new capabilities, applications, and solutions that extend and enhance the BMS.

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#### EVlink Pro AC

Monitor and control onsite electric vehicle (EV) charger energy consumption in a single view with building and power systems. See the charging stations' impact on your building's load demand and power quality, then adjust as needed.

Delivering value to every stakeholder

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See what our customers say about EcoStruxure Building Operation



Aspiria

This 200-acre mixed-use campus has improved staff productivity and shrunk its carbon footprint by over 10,000 tons.

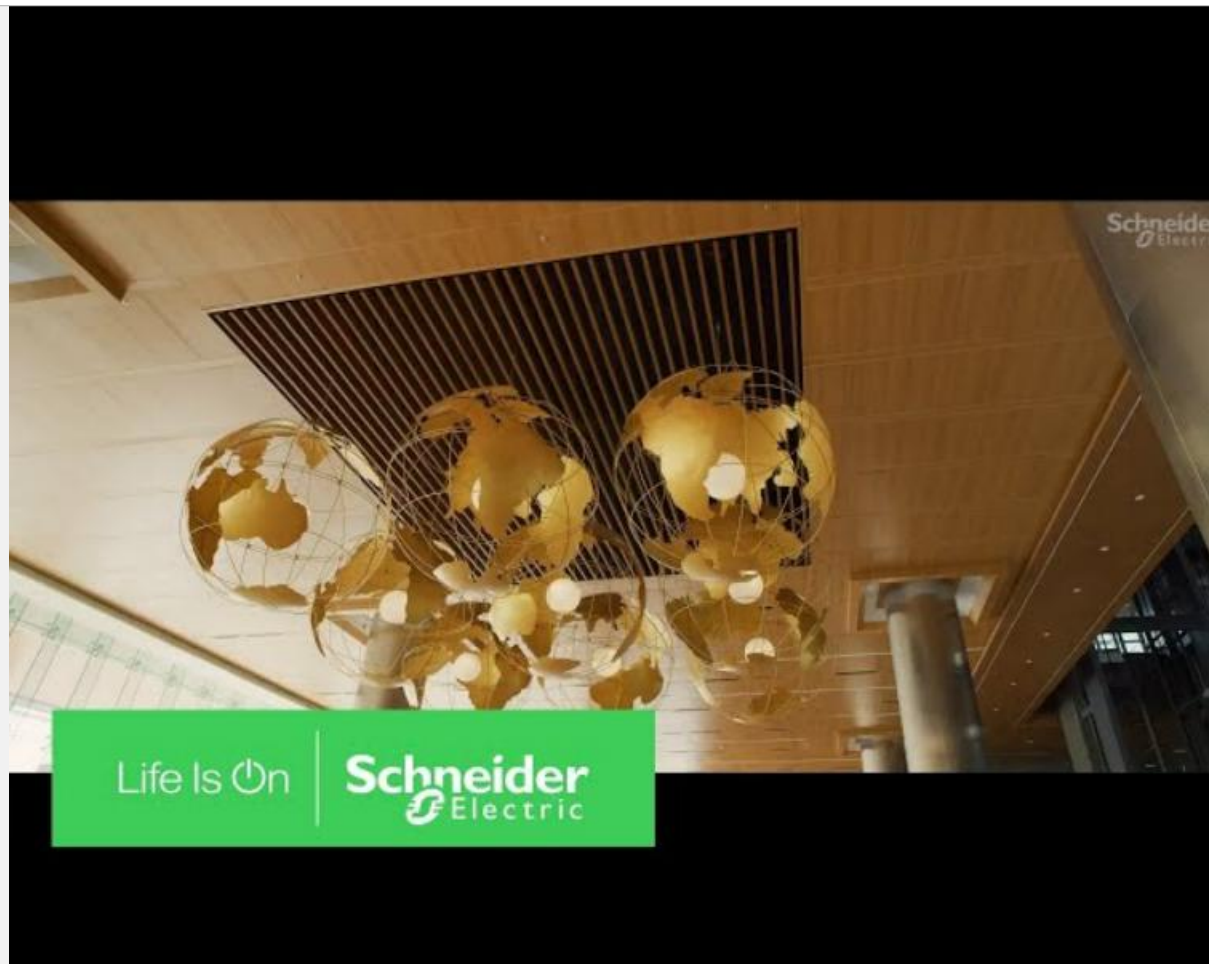
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## Resorts World

The newest Las Vegas Strip landmark ensures sustainability and scales operations efficiently to meet changing demands.

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This digital services company unified operations of HVAC, lighting, power, CCTV, and third-party systems at their headquarters in India.

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One of the United Kingdom's biggest universities improved campus operations and provided a more comfortable learning environment.

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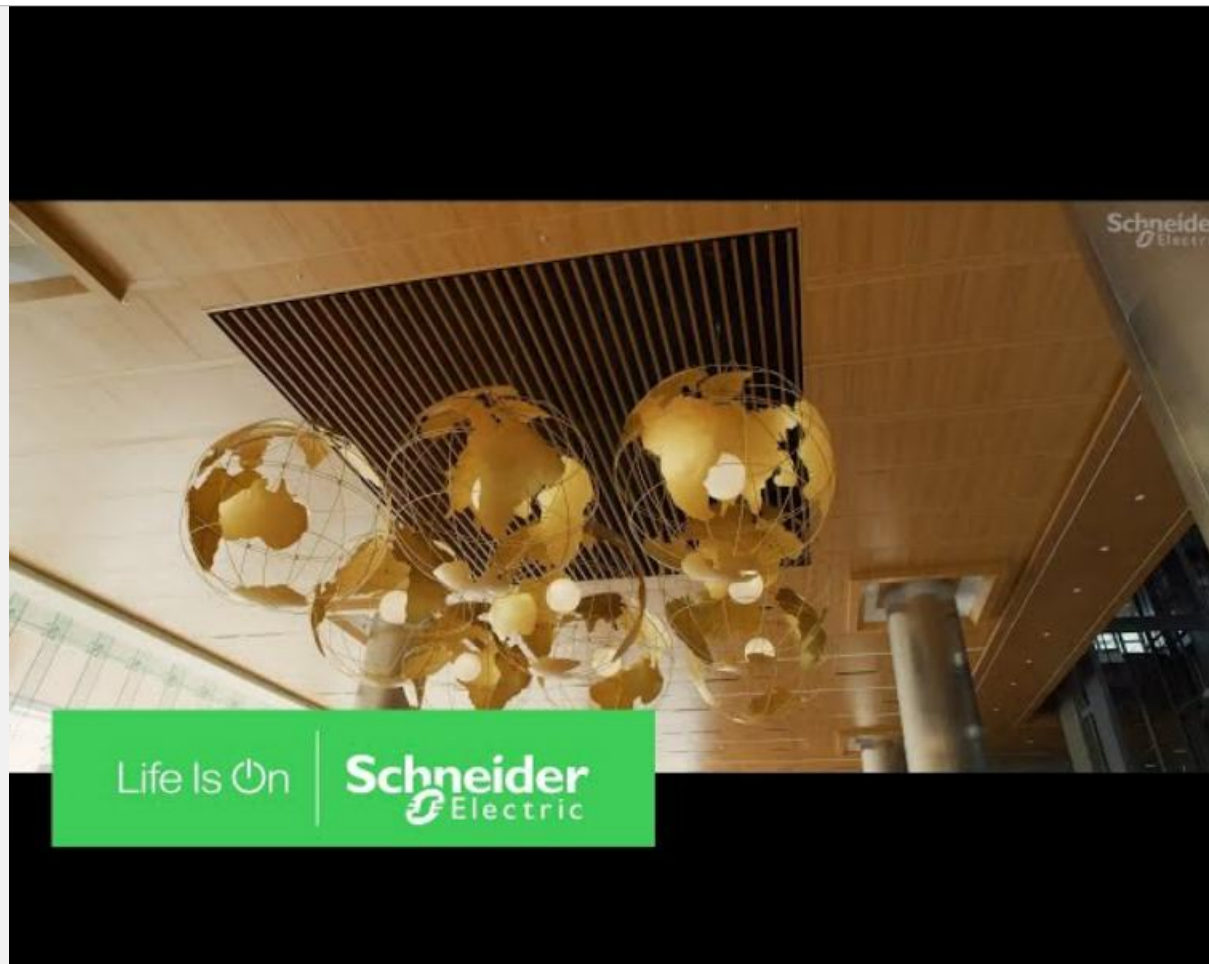
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Galaxy VX

480 V UPS System

Technical Specifications

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11/2024

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990-5451K-001 3

480 V UPS System

480 V UPS System

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## Important Safety Instructions — SAVE THESE

### INSTRUCTIONS

Read these instructions carefully and look at the equipment to become familiar with it before trying to install, operate, service or maintain it. The following safety messages may appear throughout this manual or on the equipment to warn of potential hazards or to call attention to information that clarifies or simplifies a procedure.

The addition of this symbol to a “Danger” or “Warning” safety message indicates that an electrical hazard exists which will result in personal injury if the instructions are not followed.

This is the safety alert symbol. It is used to alert you to potential personal injury hazards. Obey all safety messages with this symbol to avoid possible injury or death.

### DANGER

DANGER indicates a hazardous situation which, if not avoided, will result in death or serious injury.

Failure to follow these instructions will result in death or serious injury.

### WARNING

WARNING indicates a hazardous situation which, if not avoided, could result in death or serious injury.

Failure to follow these instructions can result in death, serious injury, or equipment damage.

## CAUTION

CAUTION indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.

Failure to follow these instructions can result in injury or equipment damage.

## NOTICE

NOTICE is used to address practices not related to physical injury. The safety alert symbol shall not be used with this type of safety message.

Failure to follow these instructions can result in equipment damage.

## Please Note

Electrical equipment should only be installed, operated, serviced, and maintained by qualified personnel. No responsibility is assumed by Schneider Electric for any consequences arising out of the use of this material.

A qualified person is one who has skills and knowledge related to the construction, installation, and operation of electrical equipment and has received safety training to recognize and avoid the hazards involved.

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Important Safety Instructions — SAVE THESE

INSTRUCTIONS 480 V UPS System

FCC Statement

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules. These limits

are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

Any changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

#### Safety Precautions

##### DANGER

##### HAZARD OF ELECTRIC SHOCK, EXPLOSION, OR ARC FLASH

- The product must be installed according to the specifications and requirements as defined by Schneider Electric. It concerns in particular the external and internal protections (upstream circuit breakers, battery circuit breakers, cabling, etc.) and environmental requirements. No responsibility is assumed by Schneider Electric if these requirements are not respected.
- After the UPS system has been electrically wired, do not start up the system.

Start-up must only be performed by Schneider Electric.

Failure to follow these instructions will result in death or serious injury.

##### DANGER

##### HAZARD OF ELECTRIC SHOCK, EXPLOSION, OR ARC FLASH

The UPS System must be installed according to local and national regulations.

Install the UPS according to:

- IEC 60364 (including 60364-4-41- protection against electric shock, 60364-4-42 - protection against thermal effect, and 60364-4-43 - protection against overcurrent), or

- NEC NFPA 70

depending on which one of the standards apply in your local area.

Failure to follow these instructions will result in death or serious injury.

**DANGER**

**HAZARD OF ELECTRIC SHOCK, EXPLOSION, OR ARC FLASH**

- Install the UPS system in a temperature controlled area free of conductive contaminants and humidity.

- Install the UPS system on a non-inflammable, level, and solid surface (e.g. concrete) that can support the weight of the system.

Failure to follow these instructions will result in death or serious injury.

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480 V UPS System

Important Safety Instructions — SAVE THESE

**INSTRUCTIONS**

**DANGER**

**HAZARD OF ELECTRIC SHOCK, EXPLOSION, OR ARC FLASH**

The UPS is not designed for and must therefore not be installed in the following

unusual operating environments:

- Damaging fumes
- Explosive mixtures of dust or gases, corrosive gases, or conductive or radiant heat from other sources
- Moisture, abrasive dust, steam or in an excessively damp environment
- Fungus, insects, vermin
- Salt-laden air or contaminated cooling refrigerant
- Pollution degree higher than 2 according to IEC 60664-1
- Exposure to abnormal vibrations, shocks, and tilting
- Exposure to direct sunlight, heat sources, or strong electromagnetic fields

Failure to follow these instructions will result in death or serious injury.

#### NOTICE

##### RISK OF OVERHEATING

Respect the clearance requirements around the UPS system and do not cover the product's ventilation openings when the UPS system is in operation.

Failure to follow these instructions can result in equipment damage.

#### NOTICE

##### RISK OF EQUIPMENT DAMAGE

Do not connect the UPS output to regenerative load systems including photovoltaic systems and speed drives.

Failure to follow these instructions can result in equipment damage.

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## Important Safety Instructions — SAVE THESE

### INSTRUCTIONS 480 V UPS System

#### Technical Data

#### System Overview

Each Galaxy VX UPS consists of the following components:

- An I/O cabinet for field wiring containing the static switch, a backfeed breaker BF21, and the user interface.
- A number of 250 kW power cabinets containing the power electronics.

#### UPSs with 1250 kW I/O Cabinet

The 1250 kW I/O cabinet is used for UPS systems from a minimum configuration of 500 kW with two power cabinets to a maximum configuration of 1250 kW N+1 with six power cabinets. The I/O cabinet is placed to the left and two to six power cabinets (depending on system size) are placed to the right. The image below shows the maximum configuration.

#### UPSs with 1500 kW I/O Cabinet

The 1500 kW I/O cabinet is used for UPS systems from a minimum configuration of 500 kW with two power cabinets to a maximum configuration of 1500 kW N+1 with seven power cabinets. The image below shows the maximum configuration.

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#### 480 V UPS System Technical Data

1. For a 1250 kW I/O cabinet, the BF2 can be installed internal in the UPS or externally in the switchgear.

#### Maintenance Bypass Cabinet for UPSs with a Maximum Rating of

750 kW

The maintenance bypass cabinet contains the following breakers to isolate the UPS during maintenance:

- Static switch input breaker (SSIB)
- Maintenance bypass breaker (MBB)
- Unit output breaker (UOB)

Maintenance Bypass Cabinet

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Technical Data 480 V UPS System

Model List

UPSs with 1250 kW I/O Cabinet

- Galaxy VX 500 kW, 480 V, start-up 5x8 (GVX500K500NGS)
- Galaxy VX 500 kW scalable to 750 kW 480 V, start-up 5x8 (GVX500K750NGS)
- Galaxy VX 500 kW scalable to 1000 kW 480 V, start-up 5x8 (GVX500K1000NGS)
- Galaxy VX 500 kW scalable to 1250 kW 480 V, start-up 5x8 (GVX500K1250NGS)
- Galaxy VX 625 kW, 480 V, start-up 5x8 (GVX625K625NGS)
- Galaxy VX 625 kW scalable to 1000 kW 480 V, start-up 5x8 (GVX625K1000NGS)
- Galaxy VX 500 kW N+1 redundant UPS 480 V, start-up 5x8

(GVX750K500NGS)

- Galaxy VX 750 kW, 480 V, start-up 5x8 (GVX750K750NGS)
- Galaxy VX 750 kW scalable to 1000 kW 480 V, start-up 5x8

(GVX750K1000NGS)

- Galaxy VX 750 kW scalable to 1250 kW 480 V, start-up 5x8

(GVX750K1250NGS)

- Galaxy VX 800 kW, 480 V, start-up 5x8 (GVX800K800NGS)
- Galaxy VX 750 kW N+1 redundant UPS 480 V, start-up 5x8

(GVX1000K750NGS)

- Galaxy VX 1000 kW, 480 V, start-up 5x8 (GVX1000K1000NGS)
- Galaxy VX 1000 kW scalable to 1250 kW 480 V, start-up 5x8

(GVX1000K1250NGS)

- Galaxy VX 1100 kW, 480 V, Start-up 5x8 (GVX1100K1100NGS)
- Galaxy VX 1000 kW N+1 redundant UPS 480 V, start-up 5x8

(GVX1250K1000NGS)

- Galaxy VX 1250 kW, 480 V, start-up 5x8 (GVX1250K1250NGS)
- Galaxy VX 1100 kW N+1 Redundant UPS 480 V, Start up 5x8

(GVX1500K1100NGS)

- Galaxy VX 1250 kW N+1 Redundant UPS 480 V, start-up 5x8

(GVX1500K1250NGS)

- Galaxy VX 1250 kW I/O Cabinet without Backfeed protection on Mains 2

(GVXI1250KDNBF2)2. Requires ordering the 250 kW power cabinets

separately.

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## 480 V UPS System Technical Data

2. Backfeed protection can be installed internally in the 1250 kW I/O cabinet with the optional backfeed kit (GVXOPT001) (ordered

separately), or installed externally upstream of the UPS in the switchgear.

UPSs with 1500 kW I/O Cabinet

- Galaxy VX 500 kW 480 V scalable to 1500 kW, start-up 5x8

(GVX500K1500GS)

- Galaxy VX 750 kW 480 V scalable to 1500 kW, start-up 5x8

(GVX750K1500GS)

- Galaxy VX 1000 kW scalable to 1500 kW 480 V, start-up 5x8

(GVX1000K1500GS)

- Galaxy VX 1250 kW scalable to 1500 kW 480 V, start-up 5x8

(GVX1250K1500GS)

- Galaxy VX 1500 kW 480 V, start-up 5x8 (GVX1500K1500GS)

- Galaxy VX 1500 kW N+1 Redundant UPS 480 V, start-up 5x8

(GVX1750K1500GS)

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## Technical Data 480 V UPS System

### Overview of Configurations

### Breakers in the System

#### UIB Unit input breaker

SSIB Static switch input breaker

BB Battery breaker

MBB Maintenance bypass breaker

UOB Unit output breaker

BF2 Backfeed protection switch

Overview of UPSs with 1250 kW I/O Cabinet - Single Utility/Mains

NOTE: Depending on your chosen configuration, the backfeed breaker BF2 (marked with \* in the illustration) can be preinstalled in the UPS, delivered as an optional backfeed kit GVXOPT001 to be installed in the UPS, or installed upstream of the UPS in the switchgear.

The illustration shows a 750 kW UPS. The principle is the same for the other UPSs with the 1250 kW I/O cabinet.

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480 V UPS System Technical Data

Overview of UPSs with 1250 kW I/O Cabinet - Dual Utility/Mains

NOTE: Depending on your chosen configuration, the backfeed breaker BF2 (marked with \* in the illustration) can be preinstalled in the UPS, delivered as an optional backfeed kit GVXOPT001 to be installed in the UPS, or installed upstream of the UPS in the switchgear.

The illustration shows a 750 kW UPS. The principle is the same for the other UPSs with the 1250 kW I/O cabinet.

Overview of UPSs with 1500 kW I/O Cabinet – Single Utility/Mains

The illustration shows a 1500 kW UPS. The principle is the same for the other UPSs with the 1500 kW I/O cabinet.

Galaxy VX 1500 kW UPS

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Technical Data 480 V UPS System

Overview of UPSs with 1500 kW I/O Cabinet – Dual Utility/Mains

The illustration shows a 1500 kW UPS. The principle is the same for the other UPSs with the 1500 kW I/O cabinet.

Galaxy VX 1500 kW UPS

Parallel System

Galaxy VX can support up to 4+0 UPSs in parallel for capacity and up to 4+1 UPSs in parallel for redundancy.

NOTE: Note that for systems over 4 MW it can be difficult to find appropriate breakers/switches in the correct size for the switchgear.

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480 V UPS System Technical Data

Input Power Factor

500 kW 625 kW 750 kW 800 kW 1000 kW 1100 kW 1250 kW 1500 kW

25% load 0.98 0.98 0.98 0.98 0.98 0.98 0.98 0.98

50% load 0.99 0.99 0.99 0.99 0.99 0.99 0.99 0.99

75% load 0.99 0.99 0.99 0.99 0.99 0.99 0.99 0.99

100% load 0.99 0.99 0.99 0.99 0.99 0.99 0.99 0.99

## Input Voltage Window

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## Technical Data 480 V UPS System

### Inverter Short-Circuit Capabilities (Bypass not Available)

#### IK1 – Short-Circuit between a Phase and Neutral

##### 480 V IK1

S [kVA] Ik10ms [A]

Normal

operation

/Battery

operation

Ik30ms [A]

Normal

operation

/Battery

operation

Ik100ms [A]

Normal

operation

/Battery

operation

Ik500ms [A]

Normal	
operation	
/Battery	
operation	
Ik1s [A]	
Normal	
operation	
/Battery	
operation	
Ik5s [A]	
Normal	
operation	
/Battery	
operation	
I2 t total [A2s]	
Normal	
operation	
/Battery	
operation	
250 –	
/810	
–	

/810	
–	
/570	
–	
/290	
–	
/290	
–	
/290	
–	
/493600	
500 –	
/1620	
–	
/1620	
–	
/1140	
–	
/580	
–	
/580	
–	

/580

–

/1974400

750 –

/2430

–

/2430

–

/1710

–

/870

–

/870

–

/870

–

/4442400

1000 –

/3240

–

/3240

–

/2280	
–	
/1160	
–	
/1160	
–	
/1160	
–	
/7897600	
1250 –	
/4050	
–	
/4050	
–	
/2850	
–	
/1450	
–	
/1450	
–	
/1450	
–	

/12340000

1500 –

/4860

–

/4860

–

/3420

–

/1740

–

/1740

–

/1740

–

/17769600

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480 V UPS System Technical Data

IK2 – Short-Circuit between Two Phases

480 V IK2

S [kVA] Ik10ms [A]

Normal

operation

/Battery

operation

1k30ms [A]

Normal

operation

/Battery

operation

1k100ms [A]

Normal

operation

/Battery

operation

1k500ms [A]

Normal

operation

/Battery

operation

1k1s [A]

Normal

operation

/Battery

operation

Ik5s [A]

Normal

operation

/Battery

operation

I2 t total [A2s]

Normal

operation

/Battery

operation

250 790

/790

770

/770

550

/550

430

/280

430

/280

280

/280

606450

/460820

500 1580 /1580 1540 /1540 1100 /1100 860

/560

860

/560

560

/560

2425800

/1843280

750 2370 /2370 2310 /2310 1650 /1650 1290

/840

1290

/840

840

/840

5458050

/4147380

1000 3160 /3160 3080 /3080 2200 /2200 1720 /1120 1720 /1120 1120 /1120  
9703200

/7373120

1250 3950 /3950 3850 /3850 2750 /2750 2150 /1400 2150 /1400 1400 /1400  
15161250

/11520500

1500 4740 /4740 4620 /4620 3300 /3300 2580 /1680 2580 /1680 1680 /1680  
21832200

/16589520

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Technical Data 480 V UPS System

IK3 – Short-Circuit between All Three Phases

480 V IK3

S [kVA] Ik10ms [A]

Normal

operation

/Battery

operation

Ik30ms [A]

Normal

operation

/Battery

operation

Ik100ms [A]

Normal

operation

/Battery

operation

Ik500ms [A]

Normal

operation

/Battery

operation

Ik1s [A]

Normal

operation

/Battery

operation

Ik5s [A]

Normal

operation

/Battery

operation

I2 t total [A2s]

Normal

operation

/Battery

operation

250 670

/660

670

/660

610

/610

440

/440

360

/440

300

/300

580600

/589380

500 1340 /1320 1340 /1320 1220 /1220 880

/880

720

/880

600

/600

2322400

/2357520

650 1742 /1716 1742 /1716 1586 /1586 1144 /1144 936

/1144

780

/780

3924856

/3984209

1000 2680 /2640 2680 /2640 2440 /2440 1760 /1760 1440 /1760 1200 /1200  
9289600

/9430080

1250 3350 /3300 3350 /3300 3050 /3050 2200 /2200 1800 /2200 1500 /1500  
14515000

/14734500

1500 4020 /3960 4020 /3960 3660 /3660 2640 /2640 2160 /2640 1800 /1800  
20901600

/21217680

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480 V UPS System Technical Data

Efficiency for UPSs with 1250 kW I/O Cabinet

Efficiency for a 500 kW UPS

Normal operation ECO mode eConversion Battery operation

Voltage (V) 480 480 480 480

25% load 94.9% 97.3% 96.9% 96.6%

50% load 95.9% 98.4% 98.2% 96.7%

75% load 96.0% 98.8% 98.7% 96.3%

100% load 95.9% 99.0% 98.9% 95.9%

Efficiency for a 625 kW UPS

Normal operation ECO mode eConversion Battery operation

Voltage (V) 480 480 480 480

25% load 95.0% 97.5% 97.1% 95.8%

50% load 96.2% 98.6% 98.4% 96.2%

75% load 96.3% 98.8% 98.7% 96.3%

100% load 96.2% 99.0% 98.9% 96.2%

Efficiency for a 750 kW UPS

Normal operation ECO mode eConversion Battery operation

Voltage (V) 480 480 480 480

25% load 95.4% 97.9% 97.7% 96.5%

50% load 96.1% 98.6% 98.5% 96.6%

75% load 96.0% 98.8% 98.7% 96.2%

100% load 95.8% 98.9% 98.9% 95.8%

Efficiency for an 800 kW UPS

Normal operation ECO mode eConversion Battery operation

Voltage (V) 480 480 480 480

25% load 95.2% 98.7% 97.4% 96.9%

50% load 96.2% 98.9% 98.5% 96.6%

75% load 96.1% 98.9% 98.8% 96.8%

100% load 96.3% 99.0% 99.1% 96.3%

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Technical Data 480 V UPS System

#### Efficiency for a 1000 kW UPS

Normal operation ECO mode eConversion Battery operation

Voltage (V) 480 480 480 480

25% load 95.6% 98.1% 97.9% 96.6%

50% load 96.3% 98.8% 98.7% 96.7%

75% load 96.2% 99.0% 98.9% 96.3%

100% load 96.0% 99.1% 99.1% 95.9%

#### Efficiency for a 1100 kW UPS

Normal operation ECO mode eConversion Battery operation

Voltage (V) 480 480 480 480

25% load 95.8% 98.3% 97.8% 96.3%

50% load 96.4% 98.9% 98.7% 96.5%

75% load 96.3% 99.0% 98.9% 96.4%

100% load 96.1% 99.1% 99.0% 96.1%

#### Efficiency for a 1250 kW UPS

Normal operation ECO mode eConversion Battery operation

Voltage (V) 480 480 480 480

25% load 95.8% 98.3% 97.9% 96.6%

50% load 96.4% 98.9% 98.7% 96.6%

75% load 96.2% 99.1% 99.0% 96.3%

100% load 96.0% 99.1% 99.1% 96.1%

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## 480 V UPS System Technical Data

### Efficiency for UPSs with 1500 kW I/O Cabinet

#### Efficiency for a 500 kW UPS

Normal operation ECO mode eConversion Battery operation

Voltage (V) 480 480 480 480

25% load 95.8% 98.5% 98.2% 95.9%

50% load 96.4% 99.1% 99.1% 96.4%

75% load 96.2% 99.2% 99.2% 96.0%

100% load 96.1% 99.2% 99.2% 95.6%

#### Efficiency for a 750 kW UPS

Normal operation ECO mode eConversion Battery operation

Voltage (V) 480 480 480 480

25% load 95.9% 98.5% 98.2% 95.9%

50% load 96.5% 99.1% 99.0% 96.4%

75% load 96.3% 99.2% 99.2% 96.0%

100% load 96.0% 99.2% 99.2% 95.6%

#### Efficiency for a 1000 kW UPS

Normal operation ECO mode eConversion Battery operation

Voltage (V) 480 480 480 480

25% load 95.9% 98.6% 98.2% 95.9%

50% load 96.5% 99.1% 99.0% 96.4%

75% load 96.4% 99.2% 99.2% 96.0%

100% load 95.9% 99.2% 99.2% 95.6%

Efficiency for a 1250 kW UPS

Normal operation ECO mode eConversion Battery operation

Voltage (V) 480 480 480 480

25% load 96.0% 98.7% 98.3% 95.9%

50% load 96.6% 99.2% 99.1% 96.4%

75% load 96.4% 99.3% 99.3% 96.0%

100% load 96.0% 99.3% 99.3% 95.6%

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Technical Data 480 V UPS System

Efficiency for a 1500 kW UPS

Normal operation ECO mode eConversion Battery operation

Voltage (V) 480 480 480 480

25% load 96.0% 98.7% 98.3% 95.9%

50% load 96.5% 99.1% 99.1% 96.4%

75% load 96.3% 99.3% 99.3% 96.1%

100% load 96.0% 99.3% 99.3% 95.7%

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480 V UPS System Technical Data

Derating Due to Load Power Factor

0.7 leading to 0.5 lagging without derating.

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## Technical Data 480 V UPS System

### Batteries (VRLA)

#### End of Discharge Voltage

The voltage is 1.6 to 1.75 per cell depending on discharge ratio.

#### Battery Voltage Range (VRLA)

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## 480 V UPS System Technical Data

### Compliance

Safety UL 1778 5th edition

EMC/EMI/RFI IEC 62040-2: 2016, 3rd edition Uninterruptible Power Systems (UPS) - Part 2: Electromagnetic compatibility

(EMC) requirements C2

FCC 15B, class A

Performance IEC 62040-3: 2011-03, 2nd edition Uninterruptible Power Systems (UPS) - Part 3: Method of specifying the

performance and test requirements

Environmental IEC 62040-4: 2013-04, 1st edition Uninterruptible Power Systems (UPS) - Part 4: Environmental aspects –

Requirements and reporting

Markings UL1778 Listing and CSA C22.2 NO.107.3

Transportation ISTA 2B

IEC 60721-4-2 Level 2M2

Seismic OSHPD, IBC2012 and CBC2013 to SDS = 1.83 g

Overvoltage

category

III

Earthing system TN, TT, IT

Protective class I

Pollution degree 2

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Technical Data 480 V UPS System

Communication and Management

Local Area Network 100 Mbps

Extensions Two optional Network Management Cards

MODBUS MODBUS TCP/IP

Relay outputs 6 configurable

Dry contact inputs 5 configurable

Standard control panel 7" touch-screen display

Audible alarm Yes

Emergency Power Off (EPO) Options:

- Normally Open (NO)
- Normally Closed (NC)
- External 24 VDC SELV

External switchgear Option containing:

- Unit Input Breaker (UIB)
- Unit Output Breaker (UOB)

- Static Switch Input Breaker (SSIB)
- Maintenance Bypass Breaker (MBB)
- System Isolation Breaker (SIB)

External synchronization Yes

Battery monitoring Yes — string level breaker monitoring

EPO Connections

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480 V UPS System Technical Data

Overview of Input Contacts and Output Relays

Input Contacts

Do not connect any circuit to the input contacts unless it can be confirmed that the circuit is Class 2/SELV.

All circuits connected must have the same 0 V reference.

The input contacts support 24 VDC 10 mA.

The switch SW5500 on OP6548 is used to select between internal SELV supply for inputs (standard setting) and external supply<sup>3</sup>. If external supply is selected, the supply must be connected to J5530.

Name Description Location

IN 1 (Contact 1) Configurable input contact OP6548 terminal J55024

IN 2 (Contact 2) Configurable input contact OP6548 terminal J55034

IN 3 (Contact 3) Configurable input contact OP6548 terminal J55044

IN 4 (Contact 4) Configurable input contact OP6548 terminal J55054

IN 5 (Contact 5) Configurable input contact OP6548 terminal J55104

IN 6 UOB redundant AUX contact OP6548 terminal J55094

IN 7 Transformer temperature switch OP6548 terminal J55084

IN 8 External bonding contact OP6548 terminal J55074

IN 9 Forced external synchronization input OP6548 terminal J55064

IN 10 External synchronization requested OP6548 terminal J55114

IN 11 Use static bypass standby OP6548 terminal J55124

IN 14 MegaTie OP6552 terminal J90274

#### Output Relays

NOTE: Maximum 250 VAC 5 A must be connected to the output relays.

All external circuitry must be fused with maximum 5 A fast acting fuses.

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#### Technical Data 480 V UPS System

3. An external supply is useful in parallel systems where inputs are connected between different UPSs. This is to have a common reference

and to avoid cross currents.

#### 4. Class 2/SELV wiring

#### Name Description Location

OUT 1 (Relay 1) Configurable output relay OP6547 terminal J4939

OUT 2 (Relay 2) Configurable output relay OP6547 terminal J4940

OUT 3 (Relay 3) Configurable output relay OP6547 terminal J4941

OUT 4 Forced external synchronization output OP6548 terminal J55205

OUT 5 MegaTie OP6548 terminal J55215

OUT 6 External synchronization requested output OP6548 terminal J55225

OUT 7 UPS in inverter ON OP6548 terminal J55235

OUT 8 (Relay 4) Configurable output relay OP6548 terminal J55245

OUT 9 (Relay 5) Configurable output relay OP6548 terminal J55255

OUT 10 (Relay 6) Configurable output relay OP6548 terminal J55285

OUT 14 Bonding contactor OP6552 terminal J90295

NOTE: Refer to the operation manual for configuration options.

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480 V UPS System Technical Data

5. Class 2/SELV wiring

Facility Planning

Specifications for 500 kW UPS

Voltage (V) 380 400 415 440 480

Input

Connections IEC: L1, L2, L3, PE 6

UL: L1, L2, L3 + G 7

Input voltage range (V) 340-456 340-480 353-498 374-528 408-576

Frequency (Hz) 40-70

Nominal input current (A) 816 775 746 699 646

Maximum input current (A) 921 885 852 798 757

Input current limitation (A) 890 832 760

Minimum short circuit rating Dependent on upstream protection. See section for 'Recommended upstream

protection and cable sizes – IEC' for details.

Maximum short circuit rating 100 kA RMS

Total harmonic distortion (THDI) <3% at 100% load, <4% at 50% load, <9% at 25% load

Input power factor 0.99 at >40% load, 0.98 at >20% load, 0.97 at >10% load

Protection Contactors

Ramp-in Adaptive 1-300 seconds

Bypass

Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE 10

UL 1250 kW I/O: L1, L2, L3, G or L1, L2, L3, N, G

UL 1500 kW I/O11: L1, L2, L3, G

Bypass voltage range (V) 342-418 360-440 374-457 396-484 432-528

Frequency (Hz) 50 or 60

Frequency range (Hz) Programmable:  $\pm 0.1$ ,  $\pm 3$ ,  $\pm 10$ . Default is  $\pm 3$

Nominal bypass current (A) 813 773 745 703 642

Minimum short circuit rating Dependent on upstream protection. See section for 'Recommended upstream

protection and cable sizes – IEC' for details.

Maximum short circuit rating 1250 kW I/O: 100 kA I<sub>cw</sub>

1500 kW I/O: 100 kA RMS (conditioned by an internal molded switch with 90 kA peak

magnetic trip)

Thyristor I<sup>2</sup>t (kA\*s<sup>2</sup>) 1250 kW I/O: 9680

1500 kW I/O: 16245

1250 kW I/O: 9165

1500 kW I/O: 16245

BF2 magnetic trip 1250 kW I/O: 39 kA

1500 kW I/O: 39 kA

Protection 1250 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for

backfeed protection

1250 kW I/O with GVXOPT001 installed: Molded switch with trip for backfeed protection

1500 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for backfeed protection

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Facility Planning 480 V UPS System

6. TN, TT, and IT power distribution systems are supported.

7. WYE source – solid grounded and high resistance grounded sources are supported. Corner (line) grounding is not permitted.

8. The system can operate at 600 V for 1 minute.

9. At nominal input voltage and full charge.

10. TN, TT, and IT power distribution systems with no earthed line conductors are supported.

11. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet.

Voltage (V) 380 400 415 440 480

Output

Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE

UL 1250 kW I/O: L1, L2, L3, G, GEC12 or L1, L2, L3, N, G

UL 1500 kW I/O13: L1, L2, L3, G, GEC12

Overload capacity Normal operation: 150% for 1 minute, 125% for 10 minutes

Battery operation: 128% for 10 seconds, 115% for 1 minute

Bypass operation: 110%14 continuous, 1000% for 60 milliseconds for systems with 1250 kW I/O cabinet, and 1000% for 100 milliseconds for systems with 1500 kW I/O cabinet

Output voltage tolerance Balanced load:  $\pm 1\%$ , Unbalanced load:  $\pm 3\%$

Dynamic load response  $\pm 5\%$  after 2 ms,  $\pm 1\%$  after 50 ms

Output power factor 1

Nominal output current (A) 760 722 696 656 601

Minimum short circuit rating15 Dependent on upstream protection. See section for 'Recommended upstream

protection and cable sizes – IEC' for details.

Maximum short circuit rating16 100 kA RMS

Inverter output short circuit capabilities Varies with time. See graph and table values in Inverter Short–Circuit Capabilities

(Bypass not Available), page 18.

Total harmonic distortion (THDU)  $< 2\%$  at 100% linear load,  $< 3\%$  at 100% non-linear load

Output frequency (Hz) 50/60 (synchronized to bypass), 50/60 Hz  $\pm 0.1\%$  (free-running)

Slew rate (Hz/sec) Programmable: 0.25, 0.5, 1, 2, 4, 6

Output performance classification

(according to IEC/ EN62040-3)

Double-conversion: VFI-SS-111

Load crest factor Up to 3 (THDU < 5%)

Load power factor 0.7 leading to 0.5 lagging without derating

Battery (VRLA)

Charging power in % of output power 35% at  $\leq 80\%$  load, 12% at 100% load 40% at  $\leq 80\%$  load,

15% at 100% load

Maximum charging power (kW) 60 at 100% load, 175 at  $<80\%$  load 75 at 100% load, 200

at 80% load

Nominal battery voltage (VDC) 480

Nominal float voltage (VDC) 546

End of discharge voltage (full load) (VDC) 384

End of discharge voltage (no load) (VDC) 420

Battery current at full load and nominal

battery voltage (A)

1090

Battery current at full load and minimum

battery voltage (A)

1362

Maximum short circuit rating 50 kA

Maximum battery backup time Unlimited

Temperature compensation (per cell) -3.3 mV per °C for  $T \geq 25\text{ °C}$ , 0 mV per °C for  $T < 25\text{ °C}$

Ripple current < 5% C20 (5-minute backup time)

Battery test Manual/automatic (selectable)

Deep discharge protection Yes

Recharge according to battery temperature Yes

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480 V UPS System Facility Planning

12. Per NEC 250.30.

13. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet.

14. 125% for 480 V.

15. Minimum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration.

16. Maximum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration.

Specifications for 625 kW UPS

Voltage (V) 380 400 415 440 480

Input

Connections IEC: L1, L2, L3, PE 17

UL: L1, L2, L3 + G 18

Input voltage range (V) 19 340-456 340-480 353-498 374-528 408-576

Frequency (Hz) 40-70

Nominal input current (A) 1021 969 932 870 807

Maximum input current (A) 20 1151 1106 1065 994 946

Input current limitation (A) 1113 1040 950

Minimum short circuit rating Dependent on upstream protection. See section for 'Recommended upstream

protection and cable sizes – IEC' for details.

Maximum short circuit rating 100 kA RMS

Total harmonic distortion (THDI) <3% at 100% load, <4% at 50% load, <9% at 25% load

Input power factor 0.99 at >40% load, 0.98 at >20% load, 0.97 at >10% load

Protection Contactors

Ramp-in Adaptive 1-300 seconds

Bypass

Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE 21

UL 1250 kW I/O: L1, L2, L3, G or L1, L2, L3, N, G

UL 1500 kW I/O22: L1, L2, L3, G

Bypass voltage range (V) 342-418 360-440 374-457 396-484 432-528

Frequency (Hz) 50 or 60

Frequency range (Hz) Programmable:  $\pm 0.1$ ,  $\pm 3$ ,  $\pm 10$ . Default is  $\pm 3$

Nominal bypass current (A) 1017 966 931 878 802

Minimum short circuit rating Dependent on upstream protection. See section for 'Recommended upstream

protection and cable sizes – IEC' for details.

Maximum short circuit rating 1250 kW I/O: 100 kA Icw

1500 kW I/O: 100 kA RMS (conditioned by an internal molded switch with 90 kA peak

magnetic trip)

Thyristor  $I^2t$  (kA\*s<sup>2</sup>) 9680 (1250 kW I/O) 9165 (1250 kW I/O)

BF2 magnetic trip 1250 kW I/O: 39 kA

1500 kW I/O: 39 kA

Protection 1250 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for

backfeed protection

1250 kW I/O with GVXOPT001 installed: Molded switch with trip for backfeed protection

1500 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for backfeed protection

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Facility Planning 480 V UPS System

17. TN, TT, and IT power distribution systems are supported.

18. WYE source – solid grounded and high resistance grounded sources are supported. Corner (line) grounding is not permitted.

19. The system can operate at 600 V for 1 minute.

20. At nominal input voltage and full charge.

21. TN, TT, and IT power distribution systems with no earthed line conductors are supported.

22. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet.

Voltage (V) 380 400 415 440 480

## Output

Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE

UL 1250 kW I/O: L1, L2, L3, G, GEC23 or L1, L2, L3, N, G

UL 1500 kW I/O<sup>24</sup>: L1, L2, L3, G, GEC23

Overload capacity Normal operation: 150% for 1 minute, 125% for 10 minutes

Battery operation: 128% for 10 seconds, 115% for 1 minute

Bypass operation: 110%<sup>25</sup> continuous, 1000% for 60 milliseconds for systems with 1250 kW I/O cabinet, and 1000% for 100 milliseconds for systems with 1500 kW I/O cabinet

Output voltage tolerance Balanced load:  $\pm 1\%$ , Unbalanced load:  $\pm 3\%$

Dynamic load response  $\pm 5\%$  after 2 ms,  $\pm 1\%$  after 50 ms

Output power factor 1

Nominal output current (A) 950 902 870 820 752

Minimum short circuit rating<sup>26</sup> Dependent on upstream protection. See section for 'Recommended upstream

protection and cable sizes – IEC' for details.

Maximum short circuit rating<sup>27</sup> 100 kA RMS

Inverter output short circuit capabilities Varies with time. See graph and table values in Inverter Short-Circuit Capabilities

(Bypass not Available), page 18.

Total harmonic distortion (THDU)  $< 2\%$  at 100% linear load,  $< 3\%$  at 100% non-linear load

Output frequency (Hz) 50/60 (synchronized to bypass), 50/60 Hz  $\pm 0.1\%$  (free-running)

Slew rate (Hz/sec) Programmable: 0.25, 0.5, 1, 2, 4, 6

Output performance classification

(according to IEC/ EN62040-3)

Double-conversion: VFI-SS-111

Load crest factor Up to 3 (THDU < 5%)

Load power factor 0.7 leading to 0.5 lagging without derating

Battery (VRLA)

Charging power in % of output power 35% at  $\leq 80\%$  load, 12% at 100% load 40% at  $\leq 80\%$  load,

15% at 100% load

Maximum charging power (kW) 75 at 100% load, 218.75 at  $<80\%$  load 93.75 at 100% load,

250 at 80% load

Nominal battery voltage (VDC) 480

Nominal float voltage (VDC) 546

End of discharge voltage (full load) (VDC) 384

End of discharge voltage (no load) (VDC) 420

Battery current at full load and nominal

battery voltage (A)

1362

Battery current at full load and minimum

battery voltage (A)

1703

Maximum short circuit rating 50 kA

Maximum battery backup time Unlimited

Temperature compensation (per cell) -3.3 mV per °C for  $T \geq 25\text{ °C}$ , 0 mV per °C for  $T < 25\text{ °C}$

Ripple current < 5% C20 (5-minute backup time)

Battery test Manual/automatic (selectable)

Deep discharge protection Yes

Recharge according to battery temperature Yes

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480 V UPS System Facility Planning

23. Per NEC 250.30.

24. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet.

25. 125% for 480 V.

26. Minimum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration.

27. Maximum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration.

Specifications for 750 kW UPS

Voltage (V) 380 400 415 440 480

Input

Connections IEC: L1, L2, L3, PE 28

UL: L1, L2, L3 + G 29

Input voltage range (V) 30 340-456 340-480 353-498 374-528 408-576

Frequency (Hz) 40-70

Nominal input current (A) 1225 1162 1119 1050 969

Maximum input current (A) 31 1381 1327 1278 1199 1136

Input current limitation (A) 1335 1248 1140

Minimum short circuit rating Dependent on upstream protection. See section for 'Recommended upstream

protection and cable sizes – IEC' for details.

Maximum short circuit rating 100 kA RMS

Total harmonic distortion (THDI) <3% at 100% load, <4% at 50% load, <9% at 25% load

Input power factor 0.99 at >40% load, 0.98 at >20% load, 0.97 at >10% load

Protection Contactors

Ramp-in Adaptive 1-300 seconds

Bypass

Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE 32

UL 1250 kW I/O: L1, L2, L3, G or L1, L2, L3, N, G

UL 1500 kW I/O 33: L1, L2, L3, G

Bypass voltage range (V) 342-418 360-440 374-457 396-484 432-528

Frequency (Hz) 50 or 60

Frequency range (Hz) Programmable:  $\pm 0.1$ ,  $\pm 3$ ,  $\pm 10$ . Default is  $\pm 3$

Nominal bypass current (A) 1220 1159 1117 1054 964

Minimum short circuit rating Dependent on upstream protection. See section for 'Recommended upstream

protection and cable sizes – IEC' for details.

Maximum short circuit rating 1250 kW I/O: 100 kA l<sub>cw</sub>

1500 kW I/O: 100 kA RMS (conditioned by an internal molded switch with 90 kA peak

magnetic trip)

Thyristor I<sup>2</sup>t (kA\*s<sup>2</sup>) 1250 kW I/O: 9680

1500 kW I/O: 16245

1250 kW I/O: 9165

1500 kW I/O: 16245

BF2 magnetic trip 1250 kW I/O: 39 kA

1500 kW I/O: 39 kA

Protection 1250 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for

backfeed protection

1250 kW I/O with GVXOPT001 installed: Molded switch with trip for backfeed

protection

1500 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for

backfeed protection

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Facility Planning 480 V UPS System

28. TN, TT, and IT power distribution systems are supported.

29. WYE source – solid grounded and high resistance grounded sources are supported. Corner (line) grounding is not permitted.

30. The system can operate at 600 V for 1 minute.

31. At nominal input voltage and full charge.

32. TN, TT, and IT power distribution systems with no earthed line conductors are supported.

33. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet.

Voltage (V) 380 400 415 440 480

Output

Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE

UL 1250 kW I/O: L1, L2, L3, G, GEC34 or L1, L2, L3, N, G

UL 1500 kW I/O35: L1, L2, L3, G, GEC34

Overload capacity Normal operation: 150% for 1 minute, 125% for 10 minutes

Battery operation: 128% for 10 seconds, 115% for 1 minute

Bypass operation: 110%<sup>36</sup> continuous, 1000% for 60 milliseconds for systems with 1250 kW I/O cabinet, and 1000% for 100 milliseconds for systems with 1500 kW I/O cabinet

Output voltage tolerance Balanced load:  $\pm 1\%$ , Unbalanced load:  $\pm 3\%$

Dynamic load response  $\pm 5\%$  after 2 ms,  $\pm 1\%$  after 50 ms

Output power factor 1

Nominal output current (A) 1140 1083 1043 984 902

Minimum short circuit rating<sup>37</sup> Dependent on upstream protection. See section for 'Recommended upstream

protection and cable sizes – IEC' for details.

Maximum short circuit rating<sup>38</sup> 100 kA RMS

Inverter output short circuit capabilities Varies with time. See graph and table values in Inverter Short-Circuit Capabilities

(Bypass not Available), page 18.

Total harmonic distortion (THDU) <2% at 100% linear load, <3% at 100% non-linear load

Output frequency (Hz) 50/60 (synchronized to bypass), 50/60 Hz  $\pm 0.1\%$  (free-running)

Slew rate (Hz/sec) Programmable: 0.25, 0.5, 1, 2, 4, 6

Output performance classification

(according to IEC/ EN62040-3)

Double-conversion: VFI-SS-111

Load crest factor Up to 3 (THDU < 5%)

Load power factor 0.7 leading to 0.5 lagging without derating

Battery (VRLA)

Charging power in % of output power 35% at  $\leq 80\%$  load, 12% at 100% load 40% at  $\leq 80\%$  load,

15% at 100% load

Maximum charging power (kW) 90 at 100% load, 262 at  $<80\%$  load 112.5 at 100% load,

300 at 80% load

Nominal battery voltage (VDC) 480

Nominal float voltage (VDC) 546

End of discharge voltage (full load) (VDC) 384

End of discharge voltage (no load) (VDC) 420

Battery current at full load and nominal

battery voltage (A)

1634

Battery current at full load and minimum

battery voltage (A)

2043

Maximum short circuit rating 50 kA

Maximum battery backup time Unlimited

Temperature compensation (per cell) -3.3 mV per °C for  $T \geq 25\text{ °C}$ , 0 mV per °C for  $T < 25\text{ °C}$

Ripple current < 5% C20 (5-minute backup time)

Battery test Manual/automatic (selectable)

Deep discharge protection Yes

Recharge according to battery temperature Yes

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480 V UPS System Facility Planning

34. Per NEC 250.30.

35. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet.

36. 125% for 480 V.

37. Minimum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration.

38. Maximum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration.

Specifications for 800 kW UPS

Voltage (V) 380 400 415 440 480

## Input

Connections IEC: L1, L2, L3, PE 39

UL: L1, L2, L3 + G 40

Input voltage range (V) 41 340-456 340-480 353-498 374-528 408-576

Frequency (Hz) 40-70

Nominal input current (A) 1307 1239 1193 1120 1033

Maximum input current (A) 42 1474 1415 1363 1279 1212

Input current limitation (A) 1424 1331 1216

Minimum short circuit rating Dependent on upstream protection. See section for 'Recommended upstream

protection and cable sizes – IEC' for details.

Maximum short circuit rating 100 kA RMS

Total harmonic distortion (THDI) <3% at 100% load, <4% at 50% load, <9% at 25% load

Input power factor 0.99 at >40% load, 0.98 at >20% load, 0.97 at >10% load

## Protection Contactors

Ramp-in Adaptive 1-300 seconds

## Bypass

Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE 43

UL 1250 kW I/O: L1, L2, L3, G or L1, L2, L3, N, G

UL 1500 kW I/O44: L1, L2, L3, G

Bypass voltage range (V) 342-418 360-440 374-457 396-484 432-528

Frequency (Hz) 50 or 60

Frequency range (Hz) Programmable:  $\pm 0.1$ ,  $\pm 3$ ,  $\pm 10$ . Default is  $\pm 3$

Nominal bypass current (A) 1302 1236 1191 1124 1027

Minimum short circuit rating Dependent on upstream protection. See section for 'Recommended upstream

protection and cable sizes – IEC' for details.

Maximum short circuit rating 1250 kW I/O: 100 kA Icw

1500 kW I/O: 100 kA RMS (conditioned by an internal molded switch with 90 kA peak

magnetic trip)

Thyristor  $I^2t$  (kA\*s<sup>2</sup>) 9680 (1250 kW I/O) 9165 (1250 kW I/O)

BF2 magnetic trip 1250 kW I/O: 39 kA

1500 kW I/O: 39 kA

Protection 1250 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for

backfeed protection

1250 kW I/O with GVXOPT001 installed: Molded switch with trip for backfeed protection

1500 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for backfeed protection

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Facility Planning 480 V UPS System

39. TN, TT, and IT power distribution systems are supported.

40. WYE source – solid grounded and high resistance grounded sources are supported. Corner (line) grounding is not permitted.

41. The system can operate at 600 V for 1 minute.

42. At nominal input voltage and full charge.

43. TN, TT, and IT power distribution systems with no earthed line conductors are supported.

44. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet.

Voltage (V) 380 400 415 440 480

Output

Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE

UL 1250 kW I/O: L1, L2, L3, G, GEC45 or L1, L2, L3, N, G

UL 1500 kW I/O46: L1, L2, L3, G, GEC45

Overload capacity Normal operation: 150% for 1 minute, 125% for 10 minutes

Battery operation: 128% for 10 seconds, 115% for 1 minute

Bypass operation: 110%<sup>47</sup> continuous, 1000% for 60 milliseconds for systems with 1250 kW I/O cabinet, and 1000% for 100 milliseconds for systems with 1500 kW I/O cabinet

Output voltage tolerance Balanced load:  $\pm 1\%$ , Unbalanced load:  $\pm 3\%$

Dynamic load response  $\pm 5\%$  after 2 ms,  $\pm 1\%$  after 50 ms

Output power factor 1

Nominal output current (A) 1216 1155 1113 1050 962

Minimum short circuit rating<sup>48</sup> Dependent on upstream protection. See section for 'Recommended upstream

protection and cable sizes – IEC' for details.

Maximum short circuit rating<sup>49</sup> 100 kA RMS

Inverter output short circuit capabilities Varies with time. See graph and table values in Inverter Short-Circuit Capabilities

(Bypass not Available), page 18.

Total harmonic distortion (THDU) <2% at 100% linear load, <3% at 100% non-linear load

Output frequency (Hz) 50/60 (synchronized to bypass), 50/60 Hz  $\pm 0.1\%$  (free-running)

Slew rate (Hz/sec) Programmable: 0.25, 0.5, 1, 2, 4, 6

Output performance classification

(according to IEC/ EN62040-3)

Double-conversion: VFI-SS-111

Load crest factor Up to 3 (THDU < 5%)

Load power factor 0.7 leading to 0.5 lagging without derating

Battery (VRLA)

Charging power in % of output power 35% at  $\leq 80\%$  load, 12% at 100% load 40% at  $\leq 80\%$  load,

15% at 100% load

Maximum charging power (kW) 96 at 100% load, 280 at <80% load 120 at 100% load, 320

at 80% load

Nominal battery voltage (VDC) 480

Nominal float voltage (VDC) 546

End of discharge voltage (full load) (VDC) 384

End of discharge voltage (no load) (VDC) 420

Battery current at full load and nominal

battery voltage (A)

1743

Battery current at full load and minimum

battery voltage (A)

2179

Maximum short circuit rating 50 kA

Maximum battery backup time Unlimited

Temperature compensation (per cell) -3.3 mV per °C for  $T \geq 25\text{ °C}$ , 0 mV per °C for  $T < 25\text{ °C}$

Ripple current < 5% C20 (5-minute backup time)

Battery test Manual/automatic (selectable)

Deep discharge protection Yes

Recharge according to battery temperature Yes

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480 V UPS System Facility Planning

45. Per NEC 250.30.

46. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet.

47. 125% for 480 V.

48. Minimum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration.

49. Maximum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration.

Specifications for 1000 kW UPS

Voltage (V) 380 400 415 440 480

Input

Connections IEC: L1, L2, L3, PE 50

UL: L1, L2, L3 + G 51

Input voltage range (V) 52 340-456 340-480 353-498 374-528 408-576

Frequency (Hz) 40-70

Nominal input current (A) 1633 1549 1492 1397 1291

Maximum input current (A) 53 1842 1770 1704 1595 1514

Input current limitation (A) 1780 1664 1520

Minimum short circuit rating Dependent on upstream protection. See section for 'Recommended upstream

protection and cable sizes – IEC' for details.

Maximum short circuit rating 100 kA RMS

Total harmonic distortion (THDI) <3% at 100% load, <4% at 50% load, <9% at 25% load

Input power factor 0.99 at >40% load, 0.98 at >20% load, 0.97 at >10% load

Protection Contactors

Ramp-in Adaptive 1-300 seconds

Bypass

Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE 54

UL 1250 kW I/O: L1, L2, L3, G or L1, L2, L3, N, G

UL 1500 kW I/O55: L1, L2, L3, G

Bypass voltage range (V) 342-418 360-440 374-457 396-484 432-528

Frequency (Hz) 50 or 60

Frequency range (Hz) Programmable:  $\pm 0.1$ ,  $\pm 3$ ,  $\pm 10$ . Default is  $\pm 3$

Nominal bypass current (A) 1627 1545 1489 1405 1284

Minimum short circuit rating Dependent on upstream protection. See section for 'Recommended upstream

protection and cable sizes – IEC' for details.

Maximum short circuit rating 1250 kW I/O: 100 kA Icw

1500 kW I/O: 100 kA RMS (conditioned by an internal molded switch with 90 kA peak

magnetic trip)

Thyristor  $I^2t$  (kA\*s<sup>2</sup>) 1250 kW I/O: 9680

1500 kW I/O: 16245

1250 kW I/O: 9165

1500 kW I/O: 16245

BF2 magnetic trip 1250 kW I/O: 39 kA

1500 kW I/O: 39 kA

Protection 1250 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for

backfeed protection

1250 kW I/O with GVXOPT001 installed: Molded switch with trip for backfeed

protection

1500 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for

backfeed protection

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## Facility Planning 480 V UPS System

50. TN, TT, and IT power distribution systems are supported.

51. WYE source – solid grounded and high resistance grounded sources are supported. Corner (line) grounding is not permitted.

52. The system can operate at 600 V for 1 minute.

53. At nominal input voltage and full charge.

54. TN, TT, and IT power distribution systems with no earthed line conductors are supported.

55. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet.

Voltage (V) 380 400 415 440 480

Output

Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE

UL 1250 kw I/O: L1, L2, L3, G, GEC56 or L1, L2, L3, N, G

UL 1500 kW I/O57: L1, L2, L3, G, GEC56

Overload capacity Normal operation: 150% for 1 minute, 125% for 10 minutes

Battery operation: 128% for 10 seconds, 115% for 1 minute

Bypass operation: 110%<sup>58</sup> continuous, 1000% for 60 milliseconds for systems with 1250 kW I/O cabinet, and 1000% for 100 milliseconds for systems with 1500 kW I/O cabinet

Output voltage tolerance Balanced load:  $\pm 1\%$ , Unbalanced load:  $\pm 3\%$

Dynamic load response  $\pm 5\%$  after 2 ms,  $\pm 1\%$  after 50 ms

Output power factor 1

Nominal output current (A) 1519 1443 1391 1312 1203

Minimum short circuit rating<sup>59</sup> Dependent on upstream protection. See section for 'Recommended upstream

protection and cable sizes – IEC' for details.

Maximum short circuit rating<sup>60</sup> 100 kA RMS

Inverter output short circuit capabilities Varies with time. See graph and table values in Inverter Short-Circuit Capabilities

(Bypass not Available), page 18.

Total harmonic distortion (THDU) <2% at 100% linear load, <3% at 100% non-linear load

Output frequency (Hz) 50/60 (synchronized to bypass), 50/60 Hz  $\pm 0.1\%$  (free-running)

Slew rate (Hz/sec) Programmable: 0.25, 0.5, 1, 2, 4, 6

Output performance classification

(according to IEC/ EN62040-3)

Double-conversion: VFI-SS-111

Load crest factor Up to 3 (THDU < 5%)

Load power factor 0.7 leading to 0.5 lagging without derating

Battery (VRLA)

Charging power in % of output power 35% at  $\leq 80\%$  load, 12% at 100% load 40% at  $\leq 80\%$  load,

15% at 100% load

Maximum charging power (kW) 120 at 100% load, 350 at  $<80\%$  load 150 at 100% load, 400

at  $<80\%$  load

Nominal battery voltage (VDC) 480

Nominal float voltage (VDC) 546

End of discharge voltage (full load) (VDC) 384

End of discharge voltage (no load) (VDC) 420

Battery current at full load and nominal

battery voltage (A)

2179

Battery current at full load and minimum

battery voltage (A)

2724

Maximum short circuit rating 50 kA

Maximum battery backup time Unlimited

Temperature compensation (per cell) -3.3 mV per °C for  $T \geq 25\text{ °C}$ , 0 mV per °C for  $T < 25\text{ °C}$

Ripple current < 5% C20 (5-minute backup time)

Battery test Manual/automatic (selectable)

Deep discharge protection Yes

Recharge according to battery temperature Yes

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480 V UPS System Facility Planning

56. Per NEC 250.30.

57. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet.

58. 125% for 480 V.

59. Minimum short circuit rating for output takes backfeeding energy through the

bypass of parallel UPSs into consideration.

60. Maximum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration.

Specifications for 1100 kW UPS

Voltage (V) 380 400 415 440 480

Input

Connections IEC: L1, L2, L3, PE 61

UL: L1, L2, L3 + G 62

Input voltage range (V) 63 340-456 340-480 353-498 374-528 408-576

Frequency (Hz) 40-70

Nominal input current (A) 1796 1704 1641 1540 1421

Maximum input current (A) 64 2026 1947 1874 1759 1666

Input current limitation (A) 1958 1830 1672

Minimum short circuit rating Dependent on upstream protection. See section for 'Recommended upstream

protection and cable sizes – IEC' for details.

Maximum short circuit rating 100 kA RMS

Total harmonic distortion (THDI) <3% at 100% load, <4% at 50% load, <9% at 25% load

Input power factor 0.99 at >40% load, 0.98 at >20% load, 0.97 at >10% load

Protection Contactors

Ramp-in Adaptive 1-300 seconds

Bypass

Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE 65

UL 1250 kW I/O: L1, L2, L3, G or L1, L2, L3, N, G

UL 1500 kW I/O66: L1, L2, L3, G

Bypass voltage range (V) 342-418 360-440 374-457 396-484 432-528

Frequency (Hz) 50 or 60

Frequency range (Hz) Programmable:  $\pm 0.1$ ,  $\pm 3$ ,  $\pm 10$ . Default is  $\pm 3$

Nominal bypass current (A) 1789 1700 1639 1545 1412

Minimum short circuit rating Dependent on upstream protection. See section for 'Recommended upstream

protection and cable sizes – IEC' for details.

Maximum short circuit rating 1250 kW I/O: 100 kA I<sub>cw</sub>

1500 kW I/O: 100 kA RMS (conditioned by an internal molded switch with 90 kA peak

magnetic trip)

Thyristor I<sup>2</sup>t (kA\*s<sup>2</sup>) 9680 (1250 kW I/O) 9165 (1250 kW I/O)

BF2 magnetic trip 1250 kW I/O: 39 kA

1500 kW I/O: 39 kA

Protection 1250 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for

backfeed protection

1250 kW I/O with GVXOPT001 installed: Molded switch with trip for backfeed protection

1500 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for backfeed protection

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## Facility Planning 480 V UPS System

61. TN, TT, and IT power distribution systems are supported.

62. WYE source – solid grounded and high resistance grounded sources are supported. Corner (line) grounding is not permitted.

63. The system can operate at 600 V for 1 minute.

64. At nominal input voltage and full charge.

65. TN, TT, and IT power distribution systems with no earthed line conductors are supported.

66. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet.

Voltage (V) 380 400 415 440 480

Output

Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE

UL 1250 kw I/O: L1, L2, L3, G, GEC67 or L1, L2, L3, N, G

UL 1500 kW I/O68: L1, L2, L3, G, GEC67

Overload capacity Normal operation: 150% for 1 minute, 125% for 10 minutes

Battery operation: 128% for 10 seconds, 115% for 1 minute

Bypass operation: 110%<sup>69</sup> continuous, 1000% for 60 milliseconds for systems with 1250 kW I/O cabinet, and 1000% for 100 milliseconds for systems with 1500 kW I/O cabinet

Output voltage tolerance Balanced load:  $\pm 1\%$ , Unbalanced load:  $\pm 3\%$

Dynamic load response  $\pm 5\%$  after 2 ms,  $\pm 1\%$  after 50 ms

Output power factor 1

Nominal output current (A) 1671 1588 1530 1443 1323

Minimum short circuit rating<sup>70</sup> Dependent on upstream protection. See section for 'Recommended upstream

protection and cable sizes – IEC' for details.

Maximum short circuit rating<sup>71</sup> 100 kA RMS

Inverter output short circuit capabilities Varies with time. See graph and table values in Inverter Short-Circuit Capabilities

(Bypass not Available), page 18.

Total harmonic distortion (THDU) <2% at 100% linear load, <3% at 100% non-linear load

Output frequency (Hz) 50/60 (synchronized to bypass), 50/60 Hz  $\pm 0.1\%$  (free-running)

Slew rate (Hz/sec) Programmable: 0.25, 0.5, 1, 2, 4, 6

Output performance classification

(according to IEC/ EN62040-3)

Double-conversion: VFI-SS-111

Load crest factor Up to 3 (THDU < 5%)

Load power factor 0.7 leading to 0.5 lagging without derating

Battery (VRLA)

Charging power in % of output power 35% at  $\leq 80\%$  load, 12% at 100% load 40% at  $\leq 80\%$  load,

15% at 100% load

Maximum charging power (kW) 132 at 100% load, 385 at  $<80\%$  load 165 at 100% load, 440

at  $<80\%$  load

Nominal battery voltage (VDC) 480

Nominal float voltage (VDC) 546

End of discharge voltage (full load) (VDC) 384

End of discharge voltage (no load) (VDC) 420

Battery current at full load and nominal

battery voltage (A)

2397

Battery current at full load and minimum

battery voltage (A)

2996

Maximum short circuit rating 50 kA

Maximum battery backup time Unlimited

Temperature compensation (per cell) -3.3 mV per °C for  $T \geq 25\text{ }^{\circ}\text{C}$ , 0 mV per °C for  $T < 25\text{ }^{\circ}\text{C}$

Ripple current < 5% C20 (5-minute backup time)

Battery test Manual/automatic (selectable)

Deep discharge protection Yes

Recharge according to battery temperature Yes

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480 V UPS System Facility Planning

67. Per NEC 250.30.

68. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet.

69. 125% for 480 V.

70. Minimum short circuit rating for output takes backfeeding energy through the

bypass of parallel UPSs into consideration.

71. Maximum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration.

Specifications for 1250 kW UPS

Voltage (V) 380 400 415 440 480

Input

Connections IEC: L1, L2, L3, PE 72

UL: L1, L2, L3 + G 73

Input voltage range (V) 74 340-456 340-480 353-498 374-528 408-576

Frequency (Hz) 40-70

Nominal input current (A) 2041 1937 1865 1750 1615

Maximum input current (A) 75 2303 2212 2130 1999 1893

Input current limitation (A) 2225 2080 1900

Minimum short circuit rating Dependent on upstream protection. See section for 'Recommended upstream

protection and cable sizes – IEC' for details.

Maximum short circuit rating 100 kA RMS

Total harmonic distortion (THDI) <3% at 100% load, <4% at 50% load, <9% at 25% load

Input power factor 0.99 at >40% load, 0.98 at >20% load, 0.97 at >10% load

Protection Contactors

Ramp-in Adaptive 1-300 seconds

Bypass

Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE 76

UL 1250 kW I/O: L1, L2, L3, G or L1, L2, L3, N, G

UL 1500 kW I/O77: L1, L2, L3, G

Bypass voltage range (V) 342-418 360-440 374-457 396-484 432-528

Frequency (Hz) 50 or 60

Frequency range (Hz) Programmable:  $\pm 0.1$ ,  $\pm 3$ ,  $\pm 10$ . Default is  $\pm 3$

Nominal bypass current (A) 2033 1931 1862 1756 1605

Minimum short circuit rating Dependent on upstream protection. See section for 'Recommended upstream

protection and cable sizes – IEC' for details.

Maximum short circuit rating 1250 kW I/O: 100 kA I<sub>cw</sub>

1500 kW I/O: 100 kA RMS (conditioned by an internal molded switch with 90 kA peak

magnetic trip)

Thyristor I<sup>2</sup>t (kA\*s<sup>2</sup>) 1250 kW I/O: 9680

1500 kW I/O: 16245

1250 kW I/O: 9165

1500 kW I/O: 16245

BF2 magnetic trip 1250 kW I/O: 39 kA

1500 kW I/O: 39 kA

Protection 1250 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for

backfeed protection

1250 kW I/O with GVXOPT001 installed: Molded switch with trip for backfeed

protection

1500 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for backfeed protection

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Facility Planning 480 V UPS System

72. TN, TT, and IT power distribution systems are supported.

73. WYE source – solid grounded and high resistance grounded sources are supported. Corner (line) grounding is not permitted.

74. The system can operate at 600 V for 1 minute.

75. At nominal input voltage and full charge.

76. TN, TT, and IT power distribution systems with no earthed line conductors are supported.

77. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet.

Voltage (V) 380 400 415 440 480

Output

Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE

UL 1250 kW I/O: L1, L2, L3, G, GEC78 or L1, L2, L3, N, G

UL 1500 kW I/O79: L1, L2, L3, G, GEC78

Overload capacity Normal operation: 150% for 1 minute, 125% for 10 minutes

Battery operation: 128% for 10 seconds, 115% for 1 minute

Bypass operation: 110%80 continuous, 1000% for 60 milliseconds for systems with 1250 kW I/O cabinet, and 1000% for 100 milliseconds for systems with 1500 kW I/O cabinet

Output voltage tolerance Balanced load:  $\pm 1\%$ , Unbalanced load:  $\pm 3\%$

Dynamic load response  $\pm 5\%$  after 2 ms,  $\pm 1\%$  after 50 ms

Output power factor 1

Nominal output current (A) 1899 1804 1739 1640 1504

Minimum short circuit rating<sup>81</sup> Dependent on upstream protection. See section for 'Recommended upstream

protection and cable sizes – IEC' for details.

Maximum short circuit rating<sup>82</sup> 100 kA RMS

Inverter output short circuit capabilities Varies with time. See graph and table values in Inverter Short-Circuit Capabilities

(Bypass not Available), page 18.

Total harmonic distortion (THDU)  $< 2\%$  at 100% linear load,  $< 3\%$  at 100% non-linear load

Output frequency (Hz) 50/60 (synchronized to bypass), 50/60 Hz  $\pm 0.1\%$  (free-running)

Slew rate (Hz/sec) Programmable: 0.25, 0.5, 1, 2, 4, 6

Output performance classification

(according to IEC/ EN62040-3)

Double-conversion: VFI-SS-111

Load crest factor Up to 3 (THDU  $< 5\%$ )

Load power factor 0.7 leading to 0.5 lagging without derating

Battery (VRLA)

Charging power in % of output power 35% at  $\leq 80\%$  load, 12% at 100% load 40% at  $\leq 80\%$  load,

15% at 100% load

Maximum charging power (kW) 150 at 100% load, 437 at  $< 80\%$  load 187.5 at 100%

load,

500 at <80% load

Nominal battery voltage (VDC) 480

Nominal float voltage (VDC) 546

End of discharge voltage (full load) (VDC) 384

End of discharge voltage (no load) (VDC) 420

Battery current at full load and nominal

battery voltage (A)

2724

Battery current at full load and minimum

battery voltage (A)

3405

Maximum short circuit rating 50 kA

Maximum battery backup time 1 hour

Temperature compensation (per cell) -3.3 mV per °C for  $T \geq 25\text{ °C}$ , 0 mV per °C for  $T < 25\text{ °C}$

Ripple current < 5% C20 (5-minute backup time)

Battery test Manual/automatic (selectable)

Deep discharge protection Yes

Recharge according to battery temperature Yes

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480 V UPS System Facility Planning

78. Per NEC 250.30.

79. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet.

80. 125% for 480 V.

81. Minimum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration.

82. Maximum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration.

Specifications for 1500 kW UPS

Voltage (V) 380 400 415 440 480

Input

Connections IEC: L1, L2, L3, PE 83

UL: L1, L2, L3 + G 84

Input voltage range (V) 85 340-456 340-480 353-498 374-528 408-576

Frequency (Hz) 40-70

Nominal input current (A) 2449 2325 2238 2100 1937

Maximum input current (A) 86 2763 2654 2555 2398 2271

Input current limitation (A) 2670 2496 2280

Minimum short circuit rating Dependent on upstream protection. See section for 'Recommended upstream

protection and cable sizes – IEC' for details.

Maximum short circuit rating 100 kA RMS

Total harmonic distortion (THDI) <3% at 100% load, <4% at 50% load, <9% at 25% load

Input power factor 0.99 at >40% load, 0.98 at >20% load, 0.97 at >10% load

Protection Contactors

Ramp-in Adaptive 1-300 seconds

Bypass

Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE 87

UL 1250 kW I/O: L1, L2, L3, G or L1, L2, L3, N, G

UL 1500 kW I/O88: L1, L2, L3, G

Bypass voltage range (V) 342-418 360-440 374-457 396-484 432-528

Frequency (Hz) 50 or 60

Frequency range (Hz) Programmable:  $\pm 0.1$ ,  $\pm 3$ ,  $\pm 10$ . Default is  $\pm 3$

Nominal bypass current (A) 2440 2318 2234 2107 1926

Minimum short circuit rating Dependent on upstream protection. See section for 'Recommended upstream

protection and cable sizes – IEC' for details.

Maximum short circuit rating 1250 kW I/O: 100 kA Icw

1500 kW I/O: 100 kA RMS (conditioned by an internal molded switch with 90 kA peak

magnetic trip)

Thyristor  $I^2t$  (kA\*s<sup>2</sup>) 16245 (1500 kW I/O)

BF2 magnetic trip 1250 kW I/O: 39 kA

1500 kW I/O: 39 kA

Protection 1250 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for

backfeed protection

1250 kW I/O with GVXOPT001 installed: Molded switch with trip for backfeed

protection

1500 kW I/O with preinstalled backfeed breaker BF2: Molded switch with trip for backfeed protection

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Facility Planning 480 V UPS System

83. TN, TT, and IT power distribution systems are supported.

84. WYE source – solid grounded and high resistance grounded sources are supported. Corner (line) grounding is not permitted.

85. The system can operate at 600 V for 1 minute.

86. At nominal input voltage and full charge.

87. TN, TT, and IT power distribution systems with no earthed line conductors are supported.

88. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet.

Voltage (V) 380 400 415 440 480

Output

Connections IEC 1250 kW I/O and 1500 kW I/O: L1, L2, L3, N, PE or L1, L2, L3, PE

UL 1250 kW I/O: L1, L2, L3, G, GEC89 or L1, L2, L3, N, G

UL 1500 kW I/O90: L1, L2, L3, G, GEC89

Overload capacity 150% for 1 minute, 125% for 10 minutes (normal operation)

115% for 1 minute (battery operation)

110% continuous, 1000% for 100 milliseconds (bypass operation)

Output voltage tolerance Balanced load:  $\pm 1\%$ , Unbalanced load:  $\pm 3\%$

Dynamic load response  $\pm 5\%$  after 2 ms,  $\pm 1\%$  after 50 ms

Output power factor 1

Nominal output current (A) 2279 2165 2087 1968 1804

Minimum short circuit rating<sup>91</sup> Dependent on upstream protection. See section for 'Recommended upstream

protection and cable sizes – IEC' for details.

Maximum short circuit rating<sup>92</sup> 100 kA RMS

Inverter output short circuit capabilities Varies with time. See graph and table values in Inverter Short-Circuit Capabilities

(Bypass not Available), page 18.

Total harmonic distortion (THDU) <2% at 100% linear load, <3% at 100% non-linear load

Output frequency (Hz) 50/60 (synchronized to bypass), 50/60 Hz  $\pm 0.1\%$  (free-running)

Slew rate (Hz/sec) Programmable: 0.25, 0.5, 1, 2, 4, 6

Output performance classification

(according to IEC/ EN62040-3)

Double-conversion: VFI-SS-111

Load crest factor Up to 3 (THDU < 5%)

Load power factor 0.7 leading to 0.5 lagging without derating

Battery (VRLA)

Charging power in % of output power 35% at  $\leq 80\%$  load, 12% at 100% load 40% at  $\leq 80\%$  load,

15% at 100% load

Maximum charging power (kW) 525 at < 80% load, 180 at 100% load, 600 at <80% load, 225

at 100% load

Nominal battery voltage (VDC) 480

Nominal float voltage (VDC) 546

End of discharge voltage (full load) (VDC) 384

End of discharge voltage (no load) (VDC) 420

Battery current at full load and nominal

battery voltage (A)

3269

Battery current at full load and minimum

battery voltage (A)

4086

Maximum short circuit rating 50 kA

Maximum battery backup time 1 hour

Temperature compensation (per cell) -3.3 mV per °C for  $T \geq 25\text{ °C}$ , 0 mV per °C for  $T < 25\text{ °C}$

Ripple current < 5% C20 (5-minute backup time)

Battery test Manual/automatic (selectable)

Deep discharge protection Yes

Recharge according to battery temperature Yes

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89. Per NEC 250.30.

90. 4-wire connection with neutral is not compliant per FCC regulations for the 1500 kW I/O cabinet.

91. Minimum short circuit rating for output takes backfeeding energy through the

bypass of parallel UPSs into consideration.

92. Maximum short circuit rating for output takes backfeeding energy through the bypass of parallel UPSs into consideration.

Recommended Upstream Protection and Cable Sizes – UL

CAUTION

HAZARD OF FIRE

- Connect only to a circuit with the below specifications.
- Connect only to a circuit provided with a maximum branch circuit overcurrent protection, as specified in the UPS rating tables below, in accordance with the National Electrical Code, ANSI/NFPA70, and the Canadian Electrical Code, Part I, C22.1.

Failure to follow these instructions can result in injury or equipment damage.

NOTE: Overcurrent protection is to be provided by others.

NOTE: All wiring must comply with all applicable national and/or electrical code (National Electrical Code, ANSI/NFPA 70).

Cable sizes in this manual are based on Table 310.15 of the National Electrical Code 2014 (NEC) with the following assertions:

- 90 °C conductors (THHN) for 75 °C termination
- Not more than 3 current carrying conductors in each conduit
- An ambient temperature of max. 30 °C
- Use of copper or aluminium conductors
- 100% rated breakers

- Nominal operating conditions

If the ambient room temperature is greater than 30 °C, use larger or additional parallel conductors in accordance with the correction factors of the NEC. The maximum allowable conductor size is 600 kcmil.

Equipment Grounding Conductors (EGC) are sized in accordance with NEC Article 250.122 and Table 250.122 Minimum size equipment conductor for grounding equipment.

NOTE: Always consider the EGC size according to the complete electrical installation.

NOTE: The use of aluminium conductors can limit the number of parallel Lithium-ion battery cabinets. Contact Schneider Electric for more information.

#### NOTICE

#### RISK OF EQUIPMENT DAMAGE

To ensure correct load sharing in bypass operation in a parallel system, the following recommendations apply:

- The bypass cables must be of the same length for all UPSs.
- The output cables must be of the same length for all UPSs.
- The input cables must be of the same length for all UPSs in a single mains system.
- Cable formation recommendations must be followed.
- The reactance of busbar layout in the bypass/input and output switchgear must be the same for all UPSs.

If the above recommendations are not followed the result can be uneven load sharing in bypass and overload of individual UPSs.

Failure to follow these instructions can result in equipment damage.

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Facility Planning 480 V UPS System

Recommended Upstream Protection and Cable Sizes for 500 kW

UPS

Maximum OCPD (A) Cable size per phase (AWG/kcmil)

Copper / Aluminum

EGC cable size (AWG/kcmil)93

Copper / Aluminum

Input 800 (I<sub>r</sub> = 1.0) 2x500 / 3x400 1x1/0 / 1x3/0

Bypass 700 (I<sub>r</sub> = 1.0) 2x350 / 2x500 1x1/0 / 1x3/0

Output 700 (I<sub>r</sub> = 1.0) 2x350 / 2x500 1x1/0 / 1x3/0

Battery 1600 (I<sub>r</sub> = 0.9) 4x500 / 5x500 1x4/0 / 1x350

Recommended Upstream Protection and Cable Sizes for 625 kW

UPS

Maximum OCPD (A) Cable size per phase (AWG/kcmil)

Copper / Aluminum

EGC cable size (AWG/kcmil)93

Copper / Aluminum

Input 1000 (I<sub>r</sub> = 1.0) 3x400 / 3x600 1x2/0 / 1x4/0

Bypass 800 (I<sub>r</sub> = 1.0) 2x600 / 3x400 1x1/0 / 1x3/0

Output 800 (I<sub>r</sub> = 1.0) 2x600 / 3x400 1x1/0 / 1x3/0

Battery 2000 (I<sub>r</sub> = 0.9) 5x500 / 6x500 1x250 / 1x400

Recommended Upstream Protection and Cable Sizes for 750 kW

UPS

Maximum OCPD (A) Cable size per phase (AWG/kcmil)

Copper / Aluminum

EGC cable size (AWG/kcmil)<sup>93</sup>

Copper / Aluminum

Input 1200 (I<sub>r</sub> = 1.0) 3x600 / 4x500 1x3/0 / 1x250

Bypass 1000 (I<sub>r</sub> = 1.0) 3x400 / 3x600 1x2/0 / 1x4/0

Output 1000 (I<sub>r</sub> = 1.0) 3x400 / 3x600 1x2/0 / 1x4/0

Battery 2500 (I<sub>r</sub> = 0.9) 6x500 / 7x600 1x350 / 1x600

Recommended Upstream Protection and Cable Sizes for 800 kW

UPS

Maximum OCPD (A) Cable size per phase (AWG/kcmil)

Copper / Aluminum

EGC cable size (AWG/kcmil)<sup>93</sup>

Copper / Aluminum

Input 1600 (I<sub>r</sub> = 0.8) 4x400 / 4x600 1x4/0 / 1x350

Bypass 1000 3x400 / 3x600 1x2/0 / 1x4/0

Output 1000 3x400 / 3x600 1x2/0 / 1x4/0

Battery 2500 (Ir = 0.9) 6x500 / 7x600 1x350 / 1x600

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93. If the conductors are run in conduits, there must be one conductor in each conduit.

Recommended Upstream Protection and Cable Sizes for 1000 kW

UPS

Maximum OCPD (A) Cable size per phase (AWG/kcmil)

Copper / Aluminum

EGC cable size (AWG/kcmil)<sup>94</sup>

Copper / Aluminum

Input 1600 (Ir = 1.0) 4x600 / 5x600 1x4/0 / 1x350

Bypass 1600 (Ir = 0.8) 4x400 / 4x600 1x4/0 / 1x350

Output 1600 (Ir = 0.8) 4x400 / 4x600 1x4/0 / 1x350

Battery 3000 (Ir = 1.0) 8x500 / 9x600 1x400 / 1x600

Recommended Upstream Protection and Cable Sizes for 1100 kW

UPS

NOTE: For a 1250 I/O cabinet, it is preferred to use flexible copper power cables with as small a diameter as possible. The number of power cables needed for this kW rating will make large and inflexible power cables more difficult to install.

Maximum OCPD (A) Cable size per phase (AWG/kcmil)

Copper / Aluminum

EGC cable size (AWG/kcmil)<sup>94</sup>

Copper / Aluminum

Input 2000 (I<sub>r</sub> = 0.9) 5x500 / 6x500 1x250 / 1x400

Bypass 1600 (I<sub>r</sub> = 0.9) 4x500 / 5x500 1x4/0 / 1x350

Output 1600 (I<sub>r</sub> = 0.9) 4x500 / 5x500 1x4/0 / 1x350

Battery 3000 (I<sub>r</sub> = 1.0) 8x500 / 9x600 1x400 / 1x600

Recommended Upstream Protection and Cable Sizes for 1250 kW

UPS

NOTE: For a 1250 I/O cabinet, it is preferred to use flexible copper power cables with as small a diameter as possible. The number of power cables needed for this kW rating will make large and inflexible power cables more difficult to install.

Maximum OCPD (A) Cable size per phase (AWG/kcmil)

Copper / Aluminum

EGC cable size (AWG/kcmil)<sup>94</sup>

Copper / Aluminum

Input 2000 (I<sub>r</sub> = 1.0) 5x600 / 6x600 1x250 / 1x400

Bypass 1600 (I<sub>r</sub> = 1.0) 4x600 / 5x600 1x4/0 / 1x350

Output 1600 (I<sub>r</sub> = 1.0) 4x600 / 5x600 1x4/0 / 1x350

Battery 4000 (I<sub>r</sub> = 0.9) 9x600 / 11x600 2x250 / 2x400

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Facility Planning 480 V UPS System

94. If the conductors are run in conduits, there must be one conductor in each

conduit.

#### Recommended Upstream Protection and Cable Sizes for 1500 kW

UPS

Maximum OCPD (A) Cable size per phase (AWG/kcmil)

Copper / Aluminum

EGC cable size (AWG/kcmil)95

Copper / Aluminum

Input 250096 6x600/

8x600

1x350 / 1x400

Bypass 200096 5x600/

6x600

1x250 / 1x350

Output 200096 5x600/

6x600

1x250 / 1x350

Battery 500097 11x600/

14x600

1x700 kcmil/ –

#### Recommended Bolt and Lug Sizes for Copper Cables

Cable Size Terminal Bolt Diameter Cable Lug Type Crimping Tool Die

1/0 AWG M12 x 35 mm LCCF1/0–12–X CT930 CD-920–2/0 Black P45

2/0 AWG M12 x 35 mm LCCF2/0-12-X CT930 CD-920-3/0 Orange P50

3/0 AWG M12 x 35 mm LCCF3/0-12-X CT930 CD-920-4/0 Purple P54

250 kcmil M12 x 35 mm LCCF250-12-X CT-940CH/CT-2940 CD-920-300 White P66

300 kcmil M12 x 35 mm LCCF300-12-6 CT-940CH/CT-2940 CD-920-350 Red P71

400 kcmil M12 x 35 mm LCCF400-12-6 CT-940CH/CT-2940 CD-920-500 Brown P87

500 kcmil M12 x 35 mm LCCF500-12-6 CT-940CH/CT-2940 CD-920-500A Pink P99

600 kcmil M12 x 40 mm LCCF600-12-6 CT-940CH/CT-2940 CD-920-750 Black P106

Recommended Bolt and Lug Sizes for Aluminium Cables

Cable Size Terminal Bolt Diameter Cable Lug Type Crimping Tool Die

2/0 AWG M12 x 40 mm LAB2/0-12-5 CT930 Olive P54

3/0 AWG M12 x 40 mm LAB3/0-12-5 CT930 Ruby P60

250 kcmil M12 x 40 mm LAB250-12-5 CT930 Red P71

300 kcmil M12 x 40 mm LAB300-12-2 CT930 Blue P76

400 kcmil M12 x 40 mm LAB400-12-2 CT930 Green P94

500 kcmil M12 x 40 mm LAB500-12-2 CT930 Pink P99

600 kcmil M12 x 40 mm LAB600-12-2 CT930 Black P106

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480 V UPS System Facility Planning

95. If the conductors are run in conduits, there must be one conductor in each conduit.

96. Long-time setting (Ir) = 1.0

97. Long-time setting (Ir) = 0.9

Weights and Dimensions

## UPS Shipping Weights and Dimensions

Weight kg (lbs) Height mm (in) Width mm (in) Depth mm (in)

1250 kW I/O cabinet

(GVXI1250KDNBF2

or GVXI1250KD)

800 (1764) 2140 (84.3) 1400 (55.1) 1060 (41.8)

1500 kW I/O cabinet

(GVXI1500KD)

1060 (2337) 2140 (84.3) 2120 (83.5) 1060 (41.8)

Galaxy VX 250 kW

power cabinet

(GVXP250KD)

560 (1235) 2140 (84.3) 760 (29.9) 1060 (41.8)

NOTE: The Galaxy VX UPS consist of one 1250 kW I/O cabinet or one 1500 kW I/O cabinet and a minimum of two 250 kW power cabinets depending on your chosen configuration.

Weights and Dimensions for UPSs with 1250 kW I/O Cabinet

Commercial reference Weight kg (lbs) Height mm (in) Width mm (in) Depth mm (in)

- GVX500K500NGS
- GVX500K750NGS
- GVX500K1000NGS
- GVX500K1250NGS

Total

– Power cabinets

– I/O cabinet

1700 (3748)

2 x 540 (2 x 1190)

620 (1367)

1970 (77.6) 2400 (94.5)

2 x 600 (2 x 23.6)

1200 (47.2)

900 (35.4)

- GVX625K625NGS
- GVX625K1000NGS
- GVX750K500NGS
- GVX750K750NGS
- GVX750K1000NGS
- GVX750K1250NGS

Total

– Power cabinets

– I/O cabinet

2240 (4938)

3 x 540 (3 x 1190)

620 (1367)

1970 (77.6) 3000 (118.1)

3 x 600 (3 x 23.6)

1200 (47.2)

900 (35.4)

- GVX800K800NGS
- GVX1000K750NGS
- GVX1000K1000NGS
- GVX1000K1250NGS

Total

– Power cabinets

– I/O cabinet

2780 (6129)

4 x 540 (4 x 1190)

620 (1367)

1970 (77.6) 3600 (141.7)

4 x 600 (4 x 23.6)

1200 (47.2)

900 (35.4)

- GVX1100K1100NGS
- GVX1250K1000NGS
- GVX1250K1250NGS

Total

– Power cabinets

– I/O cabinet

3320 (7319)

5 x 540 (5 x 1190)

620 (1367)

1970 (77.6) 4200 (165.4)

5 x 600 (5 x 23.6)

1200 (47.2)

900 (35.4)

- GVX1500K1100NGS

- GVX1500K1250NGS

Total

– Power cabinets

– I/O cabinet

3860 (8510)

6 x 540 (6 x 1190)

620 (1367)

1970 (77.6) 4800 (189.0)

6 x 600 (6 x 23.6)

1200 (47.2)

900 (35.4)

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## Facility Planning 480 V UPS System

### Weights and Dimensions for UPSs with 1500 kW I/O Cabinet

Commercial reference Weight kg (lbs) Height mm (in) Width mm (in) Depth mm (in)

- GVX500K1500GS Total

- Power cabinets

- I/O cabinet

1956 (4312)

2 x 540 (2 x 1190)

876 (1931)

1970 (77.6) 3200 (126.0)

2 x 600 (2 x 23.6)

2000 (78.7)

900 (35.4)

- GVX750K1500GS Total

- Power cabinets

- I/O cabinet

2496 (5503)

3 x 540 (3 x 1190)

876 (1931)

1970 (77.6) 3800 (149.6)

3 x 600 (3 x 23.6)

2000 (78.7)

900 (35.4)

- GVX1000K1500GS Total

- Power cabinets

- I/O cabinet

3036 (6693)

4 x 540 (4 x 1190)

876 (1931)

1970 (77.6) 4400 (173.2)

4 x 600 (4 x 23.6)

2000 (78.7)

900 (35.4)

- GVX1250K1500GS Total

- Power cabinets

- I/O cabinet

3576 (7884)

5 x 540 (5 x 1190)

876 (1931)

1970 (77.6) 5000 (196.9)

5 x 600 (5 x 23.6)

2000 (78.7)

900 (35.4)

- GVX1500K1500GS Total

– Power cabinets

– I/O cabinet

4116 (9074)

6 x 540 (6 x 1190)

876 (1931)

1970 (77.6) 5600 (220.5)

6 x 600 (6 x 23.6)

2000 (78.7)

900 (35.4)

• GVX1750K1500GS Total

– Power cabinets

– I/O cabinet

4656 (10265)

7 x 540 (7 x 1190)

876 (1931)

1970 (77.6) 6200 (244.1)

7 x 600 (7 x 23.6)

2000 (78.7)

900 (35.4)

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480 V UPS System Facility Planning

Clearance

#### Clearance for UPSs with 1250 kW I/O Cabinet

NOTE: Clearance dimensions are published for airflow and service access only. Consult with the local safety codes and standards for additional requirements in your local area.

NOTE: The UPS system can be placed up against a wall and there is no requirement for rear or side access.

#### Clearance for UPSs with 1500 kW I/O Cabinet

NOTE: Clearance dimensions are published for airflow and service access only. Consult with the local safety codes and standards for additional requirements in your local area.

NOTE: The UPS system can be placed up against a wall with no requirement for rear or side access.

#### Front View

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#### Facility Planning 480 V UPS System

#### Guidance for Organizing Battery Cables

NOTE: For 3rd party batteries, use only high rate batteries for UPS applications.

NOTE: When the battery bank is placed remotely, the organizing of the cables is important to reduce voltage drop and inductance. The distance between the battery bank and the UPS must not exceed 200 m (656 ft). Contact Schneider Electric for installations with a longer distance.

NOTE: To minimize the risk of electromagnetic radiation, it is highly recommended to follow the below guidance and to use grounded metallic tray supports.

#### Cable Length

<30 m Not recommended Acceptable Recommended Recommended

31–75 m Not recommended Not recommended Acceptable Recommended

76–150 m Not recommended Not recommended Acceptable Recommended

151–200 m Not recommended Not recommended Not recommended Recommended

#### Torque Specifications

##### WARNING

##### HAZARD OF ELECTRIC SHOCK

All electrical connections must be torqued according to this table.

Failure to follow these instructions can result in death, serious injury, or equipment damage.

#### Bolt size Torque

M6 5 Nm (3.69 lb-ft)

M8 17.5 Nm (12.91 lb-ft)

M10 30 Nm (22 lb-ft)

M12 50 Nm (36.87 lb-ft)

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480 V UPS System Facility Planning

Environment

## Operating Storage

Temperature 0 °C to 40 °C (32 °F to 104 °F)

0 °C to 50 °C (32 °F to 122 °F) when

derated to 75% power<sup>98</sup>

-15 °C to 40 °C (5 °F to 104 °F) for systems

with batteries

-25 °C to 55 °C (-13 °F to 131 °F) for

systems without batteries

Relative humidity 5-95% non-condensing 10-80% non-condensing

Elevation derating according to ANSI

C57.96–1999<sup>99</sup>

1000 m (3300 ft): 1.000

1500 m (5000 ft): 0.975

2000 m (6600 ft): 0.950

2500 m (8300 ft): 0.925

3000 m (10000 ft): 0.900

0-15000 m (0-50000 ft)

Audible noise one meter (three feet) from

unit

62 dB at 70% load

69.5 dB at 100% load for 400 V systems

68 dB at 100% load for 480 V systems

Protection class IP20

Color RAL 9003 white

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Facility Planning 480 V UPS System

98. For temperatures between 40 °C (104 °F) and 50 °C (122 °F), the load power rating must be derated with 2.5% per °C of rated output

power. Above 40 °C (104 °F) the minimum input voltage is 340 V, and from 380 V to 340 V, the charge power must be linearly derated

from 12% to 1%.

99. Maximum operation elevation is 3000 m (10000 ft).

Heat Dissipation (BTU/hr) for UPSs with 1250 kW I/O

Cabinet

Heat Dissipation for 500 kW UPS

Normal operation ECO mode

Voltage (V) 380 400 415 440 V 480 V 380 400 415 440 V 480 V

25% load 17771 21504 21504 21504 22920 11385 16847 16387 14099 11835

50% load 34617 38327 38327 37397 36468 8616 11235 10360 12112 13870

75% load 56095 58889 58889 56095 53313 12924 15540 15540 15540 15540

100% load 78519 80387 78519 75723 72936 13758 17232 17232 17232 17232

eConversion Battery operation

Voltage (V) 380 400 415 440 V 480 V 380 400 415 440 V 480 V

25% load 4308 7376 6935 10264 13644 14555 15469 15011 15011 15011

50% load 13870 12990 16521 16078 15635 29110 29110 30938 30938 29110

75% load 12924 14231 14231 15540 16853 75903 47782 49160 49160 49160

100% load 17232 13758 13758 16362 18975 71083 74793 80387 80387 72936

Heat Dissipation for 625 kW UPS

Normal operation ECO mode

Voltage (V) 380 400 415 440 V 480 V 380 400 415 440 V 480 V

25% load 27469 26880 26880 26880 28059 10880 13110 13670 13670 13670

50% load 47909 47909 47909 45006 42118 11859 14044 15139 15139 15139

75% load 73611 73611 73611 67509 61451 16155 19426 19426 19426 19426

100% load 114602 100484 98149 91170 84236 23718 25901 25901 23718 21540

eConversion Battery operation

Voltage (V) 380 400 415 440 V 480 V 380 400 415 440 V 480 V

25% load 15922 15922 10880 13390 15922 17056 17056 18764 18764 18764

50% load 17337 17337 17337 17337 17337 40967 39818 38672 38672 36387

75% load 21066 21066 21066 21066 21066 61451 61451 61451 61451 61451

100% load 25901 25901 25901 24809 23718 86543 84236 100484 100484 91170

Heat Dissipation for 750 kW UPS

Normal operation ECO mode

Voltage (V) 380 400 415 440 V 480 V 380 400 415 440 V 480 V

25% load 28745 30847 30847 30847 30847 10402 13056 13723 13723 13723

50% load 56095 56095 54702 53313 51926 14231 16853 18167 18167 18167

75% load 94653 92542 86236 83097 79969 19386 23311 23311 23311 23311

100% load 146074 137523 129025 120581 112190 25848 28462 28462 28462 28462

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#### 480 V UPS System Facility Planning

##### eConversion Battery operation

Voltage (V) 380 400 415 440 V 480 V 380 400 415 440 V 480 V

25% load 15061 15061 9084 12058 15061 21832 21832 22517 22517 23203

50% load 19485 19485 19485 19485 19485 45034 43664 45034 45034 45034

75% load 25279 25279 25279 25279 25279 77888 75812 75812 75812 75812

100% load 31081 31081 31081 29771 28462 114981 112190 112190 112190  
112190

##### Heat Dissipation for 800 kW UPS

##### Normal operation ECO mode

Voltage (V) 380 400 415 440 V 480 V 380 400 415 440 V 480 V

25% load 35160 35160 34407 34407 34407 15351 15351 8988 8988 8988

50% load 59835 58349 56867 55387 53911 19378 19378 15180 15180 15180

75% load 91985 89752 85300 84190 83081 22770 22770 22770 22770 22770

100% load 131616 128620 119669 112253 104876 30360 27572 27572 27572  
27572

##### eConversion Battery operation

Voltage (V) 380 400 415 440 V 480 V 380 400 415 440 V 480 V

25% load 17497 18216 17497 17857 18216 26956 21831 21105 21105 7590

50% load 20784 20784 20784 20784 20784 50968 43662 48036 48036 48036

75% load 24865 24865 24865 24865 24865 78657 65493 67676 67676 67676

100% load 30360 30360 27572 26180 24790 113733 101935 104876 104876  
104876

## Heat Dissipation for 1000 kW UPS

### Normal operation ECO mode

Voltage (V) 380 400 415 440 V 480 V 380 400 415 440 V 480 V

25% load 36468 39259 39259 39259 39259 12112 15635 16521 16521 16521

50% load 71083 71083 69234 69234 65547 15493 18975 20721 20721 20721

75% load 120581 117778 109405 109405 101083 20637 25848 25848 25848 25848

100% load 187156 175802 164520 164520 142167 27516 30987 30987 30987 30987

### eConversion Battery operation

Voltage (V) 380 400 415 440 V 480 V 380 400 415 440 V 480 V

25% load 18297 18297 10360 14311 18297 28198 28198 29110 29110 30023

50% load 22470 22470 22470 22470 22470 58219 56397 58219 58219 58219

75% load 28462 28462 28462 28462 28462 101083 98321 98321 98321 98321

100% load 34465 34465 34465 32725 30987 149587 145873 145873 145873 145873

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## Facility Planning 480 V UPS System

### Heat Dissipation for 1100 kW UPS

### Normal operation ECO mode

Voltage (V) 380 400 415 440 V 480 V 380 400 415 440 V 480 V

25% load 43185 43185 42160 43185 41136 18173 17199 17199 16713 16227

50% load 82273 78192 76158 76158 70080 22793 22793 22793 21832 20872

75% load 132639 123409 120345 120345 108153 28433 25564 25564 26998 28433

100% load 201700 185100 180972 180972 152315 37911 37911 37911 35997

34086

eConversion Battery operation

Voltage (V) 380 400 415 440 V 480 V 380 400 415 440 V 480 V

25% load 21107 21107 20127 18173 21107 35040 37064 36051 32021 36051

50% load 24717 22793 24717 22793 24717 66050 66050 70080 64041 68063

75% load 34189 34189 34189 28433 31308 163830 102095 105121 108153 105121

100% load 53291 41744 41744 34086 37911 156383 164545 176852 160460  
152315

Heat Dissipation for 1250 kW UPS

Normal operation ECO mode

Voltage (V) 380 400 415 440 V 480 V 380 400 415 440 V 480 V

25% load 49074 49074 47909 47909 46746 20651 19544 19544 18992 18440

50% load 93492 88854 86543 83084 79637 25901 25901 25901 24809 23718

75% load 154237 143726 140237 133281 126354 35578 32311 32311 30680 29050

100% load 233945 215042 210341 193965 177708 43081 43081 43081 40906  
38734

eConversion Battery operation

Voltage (V) 380 400 415 440 V 480 V 380 400 415 440 V 480 V

25% load 22872 22872 21760 22316 22872 36387 38672 37528 37528 37528

50% load 28088 25901 28088 28088 28088 72774 72774 77345 77345 75057

75% load 35578 35578 35578 33943 32311 119455 119455 122901 122901 122901

100% load 56175 43081 43081 40906 38734 177708 186983 200969 200969  
173085

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## 480 V UPS System Facility Planning

Heat Dissipation (BTU/hr) for UPSs with 1500 kW I/O

Cabinet

Heat Dissipation for 500 kW UPS

Normal operation ECO mode

Voltage (V) 380 400 415 440 V 480 V 380 400 415 440 V 480 V

25% load 17309 16387 16387 16387 18698 5618 5618 5618 6056 6495

50% load 32774 30938 30938 31396 31855 7747 7747 7747 7747 7747

75% load 53313 50542 50542 50542 50542 11620 11620 11620 10969 10319

100% load 86017 82260 82260 75723 69234 13758 13758 13758 13758 13758

eConversion Battery operation

Voltage (V) 380 400 415 440 V 480 V 380 400 415 440 V 480 V

25% load 6495 6495 6495 7155 7818 18234 18234 18234 18234 18234

50% load 7747 7747 7747 7747 7747 31855 31855 31855 31855 31855

75% load 11620 11620 11620 10969 10319 53313 53313 53313 53313 53313

100% load 15493 13758 13758 13758 13758 78519 78519 78519 78519 78519

Heat Dissipation for 750 kW UPS

Normal operation ECO mode

Voltage (V) 380 400 415 440 V 480 V 380 400 415 440 V 480 V

25% load 26656 25271 25271 25271 27351 9084 9084 9084 9413 9742

50% load 51926 49160 49160 47782 46407 12924 12924 12924 12272 11620

75% load 86236 82053 82053 77888 73741 17430 17430 17430 16453 15478

100% load 134684 129025 129025 117778 106625 23240 23240 23240 21938

20637

eConversion Battery operation

Voltage (V) 380 400 415 440 V 480 V 380 400 415 440 V 480 V

25% load 9742 9742 9742 10733 11727 27351 27351 27351 27351 27351

50% load 12924 12924 12924 12924 12924 47782 47782 47782 47782 47782

75% load 17430 17430 17430 16453 15478 79969 79969 79969 79969 79969

100% load 23240 23240 23240 21938 20637 117778 117778 117778 117778 117778

Heat Dissipation for 1000 kW UPS

Normal operation ECO mode

Voltage (V) 380 400 415 440 V 480 V 380 400 415 440 V 480 V

25% load 36468 34617 34617 33888 36468 12112 12112 12112 12112 12112

50% load 71083 67389 67389 60137 61876 17232 17232 17232 16362 15493

75% load 123390 117778 117778 98514 95564 23240 23240 23240 21938 20637

100% load 187156 179579 179579 149141 145873 30987 30987 30987 29251 27516

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Facility Planning 480 V UPS System

eConversion Battery operation

Voltage (V) 380 400 415 440 V 480 V 380 400 415 440 V 480 V

25% load 13334 13334 13334 14313 15294 36468 35819 36468 36468 36468

50% load 17254 17254 17254 16956 16657 63710 62976 63710 63710 63710

75% load 24358 24358 24358 22496 20637 106625 104128 106625 106625 106625

100% load 31342 31342 31342 29428 27516 157038 156664 157038 157038 157038

157038

Heat Dissipation for 1250 kW UPS

Normal operation ECO mode

Voltage (V) 380 400 415 440 V 480 V 380 400 415 440 V 480 V

25% load 44427 42118 42118 42118 44427 12950 12950 12950 13497 14044

50% load 86543 81934 81934 78490 75057 19367 19367 19367 18282 17198

75% load 147223 140237 140237 129814 119455 25796 25796 25796 24172 22549

100% load 224474 215042 215042 196297 177708 30065 30065 30065 30065 30065

eConversion Battery operation

Voltage (V) 380 400 415 440 V 480 V 380 400 415 440 V 480 V

25% load 15569 15569 15569 17156 18748 45585 45585 45585 45585 45585

50% load 19394 19394 19394 19721 20047 79637 79637 79637 79637 79637

75% load 27191 27191 27191 25681 24172 133281 133281 133281 133281 133281

100% load 34838 34838 34838 32451 30065 196297 196297 196297 196297 196297

Heat Dissipation for 1500 kW UPS

Normal operation ECO mode

Voltage

(V)

380 400 415 440 V 480 V 380 400 415 440 V 480 V

25% load 53313 50542 50542 50680 53313 15540 15540 15540 16131 16853

50% load 103851 98321 98321 91275 92813 23240 23240 23240 21626 23240

75% load 176667 168285 168285 151832 147481 30956 30956 30956 28889 27059

100%

load

269368 258050 258050 234549 213250 36079 36079 36079 37428 36079

eConversion Battery operation

Voltage

(V)

380 400 415 440 V 480 V 380 400 415 440 V 480 V

25% load 18683 18683 18683 17234 22054 54702 51372 54702 54702 54285

50% load 23273 23273 23273 20325 23129 95564 95014 95564 95564 96666

75% load 32629 32629 32629 26436 27059 159938 159521 159938 159938 154530

100%

load

41806 41806 41806 35819 36079 235556 236677 235556 235556 229962

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480 V UPS System Facility Planning

Options

Configuration Options

- eConversion mode
- Single or dual feed
- Default top or bottom cable entry
- N+1 redundancy

- Up to 4+1 UPSs in parallel
- Generator compatible
- Internal synchronization to alternate source (single system)
- Seismic rated brackets included
- Touchscreen LCD
- ECO mode

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Options 480 V UPS System

Hardware Options

Power Cabinet

- Galaxy VX 250 kW power cabinet (GVXP250KD)

Lithium-Ion Battery Cabinet

- Galaxy Lithium-ion battery cabinet with 17 battery modules

(LIBSESMG17UL)

- Galaxy Lithium-ion battery communication cables 25 m (82 ft)

(LIBSEOPT001)

- Galaxy Lithium-ion Battery Cabinet SMPS AC/DC

Converter (LIBSEOPT002)

Maintenance Bypass Cabinets

- Galaxy VX 625 kW 480 V remote maintenance bypass cabinet

(GVXMBCR625KG)

- Galaxy VX 750 kW 480 V remote maintenance bypass cabinet

(GVXMBCR750KG)

#### Bypass Inductor Cabinet

- Galaxy VX 1250 kW Bypass Inductor Cabinet with Busbar Kit

(GVXINDUCASSY)

#### Network Management Cards and Accessories

- Network management card 2 with environmental monitoring (AP9635)
- Network Management Card 3 with environmental monitoring (AP9643)
- Dry contact I/O accessory (AP9810)
- Temperature sensor (AP9335T)
- Temperature and humidity sensor (AP9335TH)

#### Options

- Backfeed protection kit, 1250 kW (GVXOPT001)100
- Galaxy VX Lithium-ion BMS Power Supply Kit (GVXOPT002)100
- Symmetra PX 250/500 paralleling cable kit (25 meters (82 feet) long)

(SYOPT008)

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#### 480 V UPS System Options

100. Only applicable for 1250 kW I/O cabinet without preinstalled backfeed breaker BF2.

#### Limited Factory Warranty

#### One-Year Factory Warranty

The limited warranty provided by Schneider Electric in this Statement of Limited Factory Warranty applies only to products you purchase for your commercial or

industrial use in the ordinary course of your business.

#### Terms of Warranty

Schneider Electric warrants that the product shall be free from defects in materials and workmanship for a period of one year from the date of product start-up, when start-up is performed by Schneider Electric-authorized service personnel, or within 18 months from the shipment date from Schneider Electric, whichever occurs first.

This warranty covers repairing or replacing any defective parts including on-site labor and travel. In the event that the product fails to meet the foregoing warranty criteria, the warranty covers repairing or replacing defective parts at the sole discretion of Schneider Electric for a period of one year from the shipment date.

#### Non-transferable Warranty

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Schneider Electric warrants for the warranty period and on the terms of the warranty set forth herein that the Schneider Electric product will substantially conform to the descriptions contained in the Schneider Electric Official Published Specifications or any of the drawings certified and agreed to by contract with Schneider Electric if applicable thereto ("Specifications"). It is understood that the Specifications are not warranties of performance and not warranties of fitness for a particular purpose.

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#### Limited Factory Warranty 480 V UPS System

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480 V UPS System Limited Factory Warranty

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[ APPLICATION NOTE #187 ]

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Galaxy High Efficiency Modes  
By Jesper Johnsen, Kristian Budde

PROJECT AT A GLANCE

Project Type

High Efficiency Modes

Equipment Installed

Galaxy VS

Galaxy VM

Galaxy VL

Galaxy VX

Galaxy VXL

Rev 5.

The Galaxy VS, Galaxy VM, Galaxy VL, Galaxy VX and Galaxy VXL UPS offer a unique type of high efficiency mode: eConversion, which offers enhanced protection while delivering highest efficiency. The eConversion mode offers such a good combination of performance and efficiency that it is recommended to be used by default in the 3-phase Galaxy V series Uninterruptible Power Supplies (UPSs).

eConversion is fundamentally different than ECO mode (the traditional high-efficiency mode) since the inverter is Off in ECO Mode, whereas it is On in eConversion Mode. This means that the load is exposed directly to the unconditioned utility power in ECO Mode, while this is not the case in eConversion Mode. Here the inverter is able to run in parallel with the bypass source supplying the reactive part of the load and maintain an input power factor close to unity. In eConversion Mode it is possible to transfer back to inverter operation faster compared to ECO Mode, should it be required. When operating in eConversion the UPS is able to react to an outage as a class 1 system according to ICE 62040-3: the highest protection category.

Keeping the inverter On in eConversion mode has a minimal impact on the efficiency. The efficiency is around 99% in eConversion (as well as in ECO mode) depending on the connected load.

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Make the most of your energySM

In this context the general term 'high efficiency mode' is defined as an UPS operation mode for which the primary goal is to reduce the system power loss and increase the efficiency compared to inverter operation (battery or double conversion).

ECO MODE

ECO Mode is basically the same as transferring the UPS to Requested Static Bypass as its primary mode of operation. The static bypass switch is supplying the load

with unconditioned utility power and the inverter is off. If some sort of disturbance is detected on the bypass utility the UPS will transfer to inverter operation. In a worst case scenario this can lead to a 8 ms (at 60 Hz) or 10 ms (at 50 Hz) interruption in the output voltage.

The UPS can only be in, or transfer to, ECO Mode (or Requested Static Bypass) if all of the below conditions are fulfilled:

- The bypass utility is within the configured tolerance.
- There is no surveillance detected faults in the inverter and static bypass switch.
- The inverter is synchronized to bypass.

To avoid transferring in and out of ECO Mode because of small variations and disturbances in the bypass utility, it is recommended to keep the output voltage tolerance setting at the default value of +/- 10%.

#### User Interface

There are some consequences connected with the use of ECO Mode concerning the protection of the power to the load. It is therefore by default disabled and can only be enabled using UPSTuner.

When ECO Mode is enabled, it is possible to configure how and when ECO Mode should be used via the UPS display.

#### Setup and Configuration

The following parameters can be configured for ECO Mode:

- High Efficiency Mode: Configures which high efficiency mode the UPS should use. Value can be 'None,' 'ECO Mode,' or 'eConversion.' Must be set to ECO Mode.
- ECO Mode enable/disable: General setting to enable and disable use of the ECO Mode feature in the UPS. Can only be configured via UPSTuner.
- High Efficiency Mode Setup: Configures when the UPS transfers to ECO Mode. Selectable values are 'Never,' 'Always,' and 'Scheduled.'
  - o If 'Never' is selected, the UPS will not enter ECO Mode under any circumstances.
  - o If 'Always' is selected, the UPS will

transfer to ECO Mode whenever circumstances allow it and stay in this mode as long as circumstances allow it. ECO Mode will be the primary operation mode of the UPS.

o If 'Scheduled' is selected, the user can configure when the UPS must enter and exit ECO Mode. Up to seven different time intervals can be configured, each with a start time, a start day, a stop time and a stop day. Each of the seven intervals can be enabled and disabled separately. One interval may span over several days. The intervals must not overlap each other.

Below is a screenshot of the high efficiency mode configuration screen on the display:

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Figure 1: The high efficiency mode configuration screen in the UPS display.

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Operation

When the UPS is in ECO Mode, this will be indicated as both the system and the UPS operation mode in the UPS display and UPSTuner.

The UPS mimic diagram will indicate ECO Mode in the following way:

Figure 2: Mimic diagram indication of ECO Mode  
ECONVERSION MODE

In eConversion Mode the primary power path is the same as for ECO Mode described in the previous section, but in eConversion Mode the inverter is on and operating in parallel with bypass. Using this mode, the inverter is not continuously regenerating output power to the load like in double conversion mode. Instead, the load is receiving unconditioned bypass power.

The main advantage of eConversion Mode is that the inverter can seamlessly take over support the load in cases of bypass utility failure. The inverter is furthermore able to correct the power factor of the load and actively filter harmonic currents generated by the

load.

#### Bypass Failure

When in eConversion Mode, the inverter is operating in parallel with bypass. Thus, the inverter is continually powered and ready to take over in case of a bypass utility failure. In Figure 4 a case is shown where bypass utility is failing caused by an over current protective device supplying the UPS. The bypass utility supplying the UPS is disconnected from the inverter without changing the inverter output voltage level and the supplied load voltage level. The handover of power is easily seen on the bypass and inverter current measurement but difficult to notice on the output UPS voltage.

In Figure 5 the same scenario is repeated with an UPS in ECO Mode. The inverter voltage is much more affected by the fault occurring. In this specific case there is a break in the output UPS voltage of 4 ms before the inverter supplies the load.

Figure 3: eConversion Situation with 95% ohm load applied on a 4-wire 400 V 50 Hz system.

Blue Inverter V, Red Inverter I, Yellow Bypass V, Green Bypass I

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Figure 4: ECO mode Situation with 95% ohm load applied on a 4-wire 400 V 50 Hz system.

Blue Inverter V, Red Inverter I, Yellow Bypass V, Green Bypass I

This difference illustrates an important strength of eConversion Mode compared to ECO Mode where the prolonged detection time and powering of the inverter changes the given scenario significantly. This power failure scenario is a more common situation and a situation where eConversion Mode, supporting customer loads, can be a reliable mode of operation.

Bypass scenarios including transients like illustrated on

Figure 6 are not handled equally well when in

eConversion mode compared to the complete

suppression achieved in double conversion. In

eConversion a common mode transient is reduced approximately 7 times and a difference mode transient is reduced approximately 15 times giving a significant but no complete reduction of transients.

A situation with an abrupt change in bypass voltage is detected and reacted upon after 1 ms (the detection time of any waveform disruption when in eConversion). The reaction time for a sinusoidal RMS fault can be up to 200

ms, which is again too long for a reaction to occur in the case of a sub-cycle overvoltage like illustrated on Figure 7. Even if the faults were detected in time, it would not be possible to avoid the power from the sub-cycle overvoltage to pass through the bypass switch before next zero crossing since the SCR would continue to conduct even if it was turned off.

Figure 5: Transient occurring on grid Figure 6: Sub-cycle overvoltage  
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In other situations where transients are decreasing towards zero, or during a sub-cycle under voltage, the inverter is immediately able to support the load avoiding the grid fault to affect the connected load.

The power generated by the inverter is not reversed through bypass to utility mains since bypass is operating as one directional conductor during the operation mode of eConversion Mode.

Upstream and Downstream Short

In ECO Mode the static bypass switch is operating as a bidirectional conductor able to conduct current to and from the load. This is not the case when operating in eConversion Mode. In eConversion an advanced method of bypass operation is used (patent pending 2012/0181871). This method enables the UPS to handle occurring upstream short as illustrated in Figure 8 where a short forces bypass input to zero. From the bypass current it can be seen that no current is conducted upstream, and the inverter voltage shows that the load is continually supplied. The upstream short occurs at 180 degrees and in a no load situation, since this is one of the most difficult situations for the UPS to handle.

In Figure 9 the same test is conducted with an UPS in ECO Mode. In this case the inverter output voltage is forced to zero from the occurring upstream short until next zero crossing where both bypass SCR's are able to stop conducting. In this period, the inverter tries to take over from bypass but the inverter current is conducted from the inverter through bypass to the upstream short and therefore not powering the load, and in this case not able to clear the upstream fault.

The resonance observed on bypass and inverter

voltage, together with bypass current, is a result of the capacitance and inductance present on the grid and connected systems.

Figure 7: Upstream short when systems in eConversion Mode 0% load short at 180 degrees.

Blue bypass V, yellow bypass I, red inverter V,  
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Figure 8: Upstream short when systems in ECO Mode 0% load short at 180 degrees.

Blue bypass V, yellow bypass I, red inverter V,  
In a case with a downstream short ECO Mode and eConversion Mode have different reaction patterns compared to double conversion. A system in double conversion, which is experiencing a downstream short, will based on the large inverter current transfer to static bypass. This ensures the largest possible current resulting in a rapid clearing of a downstream protective device.

An UPS operating in ECO Mode or eConversion Mode is supplying the load through bypass. This enables a high immediate current to clear the downstream protective device, but based on an occurring output voltage waveform fault, the system will transfer to inverter operation. If the waveform fault is not cleared before transferring to inverter operation, the downstream current is limited to the abilities of the inverter. If this is not sufficient, the UPS returns to bypass operation increasing the abilities to clear downstream.

If the downstream short is cleared before transferring to inverter operation, then eConversion Mode and ECO Mode have supplied the load with the best protection. If the downstream short is not cleared when in bypass operation then the transfer process from bypass to inverter operation and then back to bypass take more time than it would in a system in double conversion and is therefore less ideal.

eConversion is a class 1 operation

Based on possible outage situations the UPS when operating in eConversion is able to react as a class 1 system according to ICE 62040-3. As illustrated in Figure 10 the system output voltage is kept within limits of a class 1 system rating.

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Figure 9: In eConversion mode the UPS is rated as a class 1 system giving zero breaks transfer at power

outage (ICE 62040-3), the same category as double conversion

PFC Off and Contactor Open

In order to decrease UPS power consumption when operating in eConversion Mode, the PFC rectifier is turned off. The system DC bus powering fans, controller, battery charger, etc. is being powered through the inverter using power from bypass.

In Figure 11 the power flow in ECO Mode is shown and the inverter is not active in charging the DC bus. Figure 12 illustrates the power flow in eConversion Mode where the DC bus is being powered from the inverter via bypass. This allows for increased system efficiency while maintaining all system functionalities. As a consequence of this, each transfer from eConversion Mode to double conversion must first rely on power from the batteries until the UPS has closed its input contactors and can draw power from the grid. This will typically result in batteries partly supplying the load for 20 seconds (adjustable) during ramp-in to mains power and will have little or no effect on the charge state of the batteries. However, this could have an effect on the battery life cycle if eConversion Mode is chosen in an installation where transfer to inverter operation is often required.

Conducting many small discharges on a battery installation can decrease the overall life expectancy of the installed batteries and is one of the reasons for the recommendation to only use eConversion Mode in installations supplied by a reliable power grid of reasonable good quality requiring few transfers from eConversion Mode to inverter operation.

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AC in

Bypass Swit

AC in Load

ch

DC/DC

PFC Rectifier

Maybe on to

allow battery  
recharge  
Battery  
Inverter

high and even though the inverter is supporting the output voltage shape, it is not controlling the harmonics. The next figure (Figure 14) illustrates the bypass current drawn by the same SMPS load, but with harmonic compensation enabled. Note that the bypass current is now more sinusoidal shaped. The inverter is working to decrease the harmonics currents generated by the load giving a unique shape of the inverter current.

The harmonics content on bypass when enabling harmonic suppression is significantly decreased as can Figure 10: In ECO Mode the DC bus is being charged through the PFC to allow the batteries to be charged.

Battery

Figure 11: In eConversion Mode the DC bus is being charged through the inverter to allow the batteries to be charged.

Harmonic Compensation and Power Factor

When operating in ECO Mode the bypass utility will receive whatever power factor and harmonic currents the load generates. This is not the case when operating in eConversion Mode. Here the inverter operating in parallel with bypass is able to correct system power factor ensuring power drawn from mains at unity power factor. It is further possible to select a suppression of harmonic currents. This enables the inverter to operate as an active filter removing most of the harmonics current content of the connected load. In practice the system is able to suppress 3', 5', and 7' harmonics since these are typically carrying the significantly largest part of the total harmonic content.

Figure 13 illustrates a SMPS load connected to a UPS in eConversion Mode with harmonic suppression disabled.

The harmonic content of the bypass current is be seen in Table 1.

This shielding of the harmonic currents generated by the load and correction of power factor protects the utility or generator power source.

Suppression of harmonic currents is by default enabled but can, though it is not recommended, be turned off if required. Correction of power factor is by default on and

can only be disabled by exiting eConversion Mode and transferring to ECO Mode.

Operation of loads where the total load is generating power (regenerative loads) is not supported by eConversion.

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Figure 12: eConversion with Harmonics Compensation disabled  
Situation with 60% SMPS load applied on at 4-wire 400 V 50 Hz system.

Blue Inverter V, Red Inverter I, Yellow Bypass V, Green Bypass I

Figure 13: eConversion with Harmonics Compensation enabled  
Situation with 60% SMPS load applied on at 4-wire 400 V 50 Hz system.

Blue Inverter V, Red Inverter I, Yellow Bypass V, Green Bypass I

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Table 1: Harmonic content in ECO Mode compared to eConversion when 60% SMPS load is applied

ECO Mode	eConversion Mode
Harmonic Input current	
harmonics [%]	
Input current	
harmonics [%]	
H3	40 2.50
H5	21 2.25
H7	7 1.07

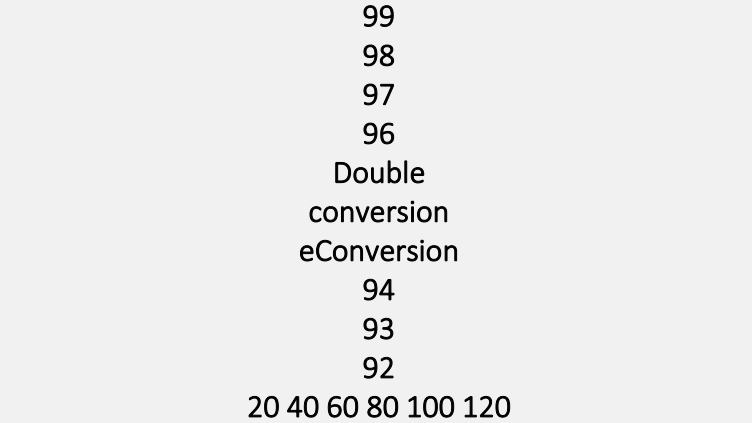
Efficiency in eConversion Mode

Given that the reason for choosing eConversion Mode as operation mode is to decrease power consumption of an installation, it is interesting to compare the loss related to the different modes of operation. Besides saving energy on the UPS as an isolated system, an additional energy saving can in some cases be achieved on UPS cooling. The evaluation of this is much more individual since it depends on the installation and chosen method of cooling (e.g. air- conditioning, ventilation) and must therefore be evaluated for the specific installation.

In Figure 15 an efficiency plot of a 200 kVA UPS in double conversion, ECO Mode and eConversion Mode can be observed. With 50% resistive load there is a gain in efficiency from 96.37% in double conversion to 98.64% in eConversion Mode. This is a significant

improvement of the UPS efficiency by up to 2.27%. The efficiency improvement in eConversion mode is dependent on the load type applied to the UPS. The more the inverter has to compensate the load current the less improvement in efficiency will be achieved compared to double conversion. For further details regarding applied load and the resulting eConversion efficiency refer to appendix A.

Figure 14: Efficiency plot data derived from Table 2 Galaxy VM



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Table 2: Derived from UL test report (10-23-2014) (IEC 62040-3: 2011-3 2nd Edition).

Double conversion			
eConversion		eConversion vs Double conversion	
Load [%]	Efficiency [%]	Efficiency [%]	Efficiency gain [%]
Galaxy VS			
50 kW 400V			
25	96.4	98	1.6
50	97	98.9	1.9
75	97	99.1	2.1
100	96.7	99.3	2.6
Galaxy VM			
200 kVA 400V			
25	93.3	94.5	1.2
50	96.4	98.6	2.2
75	96.2	99	2.8
100	95.7	99.1	3.4
Galaxy VL			
500 kW 400V			
25	96.6	98.4	1.8

50 97.1 99 1.9  
 75 96.9 99.2 2.3  
 100 96.6 99.3 2.7  
 Galaxy VX  
 1250 kW 400V  
 25 95.6 97.9 2.3  
 50 96 98.8 2.8  
 75 95.7 98.9 3.2  
 100 95.2 99 3.8  
 Galaxy VXL  
 1250 kW 400V  
 25 96.9 98.7 1.8  
 50 97.3 99.2 1.9  
 75 97.4 99.4 2.0  
 100 96.9 99.4 2.5

In average, a gain of 2-3% efficiency is observed in Galaxy V series when using eConversion rather than double conversion

#### Output Quality Settings

When operating in eConversion Mode the system output voltage is following the bypass voltage. To increase system transfer speed when a bypass waveform fault occurs, the bypass voltage fault detector has increased sensitivity. By this, a smaller waveform fault on bypass for a system in eConversion Mode will result in a transfer to double conversion. To further improve the system ability to trace the bypass source and avoid transfers from eConversion Mode to double conversion due to small phase changes, the system frequency slew rate is defaulted to maximum level when in eConversion Mode. When the UPS returns to double conversion the user adjusted values are used.

A system which is selected to operate in eConversion Mode should be configured with the widest possible range of operation. Based on this, the FSE must set the system voltage limits and frequency limits as high as possible for the given installation.

#### User Interface

eConversion Mode can be enabled and configured by the customer without the need of an FSE and UPSTuner. The user interface is almost the same as for ECO Mode, only with the addition of one parameter, the 'eConversion Harmonics Compensator.'

### Setup and configuration

The following parameters can be configured for eConversion Mode:

- High Efficiency Mode: Selects which high efficiency mode to be used. Value can be 'None,' 'ECO Mode,' or 'eConversion.' Must be set to eConversion Mode.
- High Efficiency Mode Setup: See description in section 'ECO Mode.'
  - eConversion Harmonics Compensator: Setting to enable and disable the harmonic compensator feature available in eConversion Mode.

### Operation

When the UPS is in eConversion Mode, this will be indicated as both the system and the UPS operation mode in the UPS display and UPSTuner.

The UPS mimic diagram will indicate eConversion Mode as in Figure 16.

Figure 15:

Mimic diagram indication of eConversion Mode.

### Operation Conditions and Behavior

The UPS will transfer to eConversion mode only if it is enabled via a setting, the UPS has been in inverter operation for minimum 10 seconds and the bypass utility is within the configured tolerances. Furthermore, the UPS will evaluate the operational status of the battery and the power modules to determine if the conditions allow for operating in eConversion before transferring.

Should the operation conditions change while in eConversion, so that they are no longer optimal for this operation mode, the UPS will automatically transfer back to double conversion. This would for example be the case if the bypass utility becomes

out of tolerance or the UPS output is overloaded. The UPS will automatically transfer back to eConversion again when the conditions allow for it.

If the UPS continuously transfers back and forth between eConversion and inverter operation, it indicates that the conditions are not optimal for operating in eConversion, and therefore eConversion mode will automatically be disabled by the system and the user will be notified via an alarm. The user can then manually re-enable eConversion again.

It is also possible to configure an input contact on the UPS to disable eConversion mode when the input contact is activated.

This way an external system can temporarily prevent eConversion mode without disabling it permanently if there are situations where this is desired.

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Appendix A

eConversion efficiency compared to leading load

Figure 16: System efficiency related to leading load PF 1.00 0.95 0.90 0.80.

eConversion efficiency compared to lagging load

Figure 17: System efficiency related to lagging load PF 1.00 0.95 0.90 0.80.

Galaxy VM eConversionEfficiency

Leading PF Load

99.00

98.00

97.00

96.00

1.0 Lead

0.95 Lead

0.90 Lead

0.80 Lead

95.00

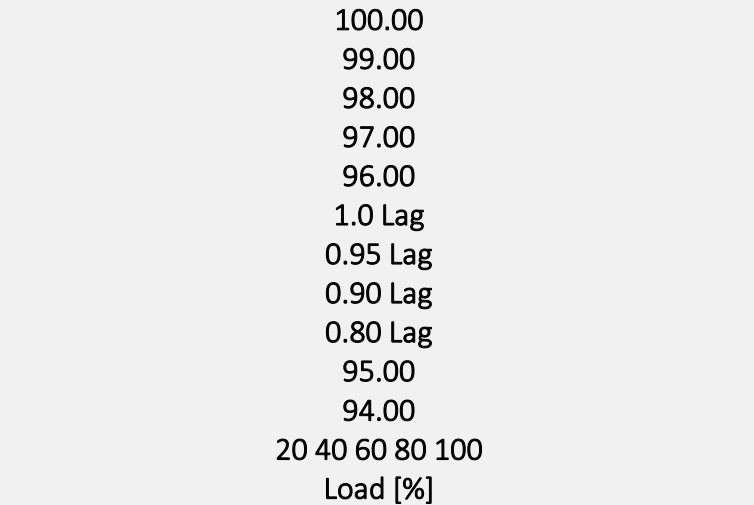
94.00

20 40 60 80 100

Load [%]

Galaxy VM eConversionEfficiency

Lagging PF Load

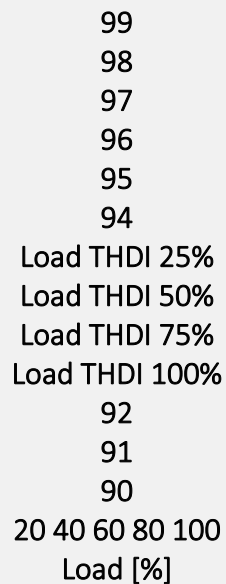


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eConversion efficiency compared to harmonic load  
Figure 18: System efficiency related to harmonic content.

Appendix B  
eConversion activation guidelines  
Figure 19: Guidelines for when to activate eConversion.

Galaxy VM eConversion  
Efficiency at Non-linear Load(Typical)



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Galaxy High Efficiency Modes  
By Jesper Johnsen, Kristian Budde

## PROJECT AT A GLANCE

Project Type

High Efficiency Modes

Equipment Installed

Galaxy VS

Galaxy VM

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Galaxy VXL

Rev 5.

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Make the most of your energySM

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The UPS can only be in, or transfer to, ECO Mode (or Requested Static Bypass) if all of the below conditions are fulfilled:

- The bypass utility is within the configured tolerance.
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To avoid transferring in and out of ECO Mode because of small variations and disturbances in the bypass utility, it is recommended to keep the output voltage tolerance setting at the default value of +/- 10%.

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- ECO Mode enable/disable: General setting to enable and disable use of the ECO Mode feature in the UPS. Can only be configured via UPSTuner.
- High Efficiency Mode Setup: Configures when the UPS transfers to ECO Mode. Selectable values are 'Never,' 'Always,' and 'Scheduled.'
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ECO Mode will be the primary operation  
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Each of the seven intervals can be  
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interval may span over several days.  
The intervals must not overlap each  
other.

Below is a screenshot of the high efficiency mode  
configuration screen on the display:

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Figure 1: The high efficiency mode configuration screen in the UPS display.

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Operation

When the UPS is in ECO Mode, this will be indicated as  
both the system and the UPS operation mode in the UPS  
display and UPSTuner.

The UPS mimic diagram will indicate ECO Mode in the  
following way:

Figure 2: Mimic diagram indication of ECO Mode  
ECONVERSION MODE

In eConversion Mode the primary power path is the  
same as for ECO Mode described in the previous  
section, but in eConversion Mode the inverter is on and  
operating in parallel with bypass. Using this mode, the  
inverter is not continuously regenerating output power  
to the load like in double conversion mode. Instead, the  
load is receiving unconditioned bypass power.

The main advantage of eConversion Mode is that the  
inverter can seamlessly take over support the load in  
cases of bypass utility failure. The inverter is  
furthermore able to correct the power factor of the load  
and actively filter harmonic currents generated by the  
load.

Bypass Failure

When in eConversion Mode, the inverter is operating in parallel with bypass. Thus, the inverter is continually powered and ready to take over in case of a bypass utility failure. In Figure 4 a case is shown where bypass utility is failing caused by an over current protective device supplying the UPS. The bypass utility supplying the UPS is disconnected from the inverter without changing the inverter output voltage level and the supplied load voltage level. The handover of power is easily seen on the bypass and inverter current measurement but difficult to notice on the output UPS voltage.

In Figure 5 the same scenario is repeated with an UPS in ECO Mode. The inverter voltage is much more affected by the fault occurring. In this specific case there is a break in the output UPS voltage of 4 ms before the inverter supplies the load.

Figure 3: eConversion Situation with 95% ohm load applied on a 4-wire 400 V 50 Hz system.

Blue Inverter V, Red Inverter I, Yellow Bypass V, Green Bypass I

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Figure 4: ECO mode Situation with 95% ohm load applied on a 4-wire 400 V 50 Hz system.

Blue Inverter V, Red Inverter I, Yellow Bypass V, Green Bypass I

This difference illustrates an important strength of eConversion Mode compared to ECO Mode where the prolonged detection time and powering of the inverter changes the given scenario significantly. This power failure scenario is a more common situation and a situation where eConversion Mode, supporting customer loads, can be a reliable mode of operation. Bypass scenarios including transients like illustrated on Figure 6 are not handled equally well when in eConversion mode compared to the complete suppression achieved in double conversion. In eConversion a common mode transient is reduced approximately 7 times and a difference mode transient is reduced approximately 15 times giving a significant but no complete reduction of transients.

A situation with an abrupt change in bypass voltage is detected and reacted upon after 1 ms (the detection time of any waveform disruption when in eConversion). The reaction time for a sinusoidal RMS fault can be up to 200 ms, which is again too long for a reaction to occur in the case of a sub-cycle overvoltage like illustrated on Figure

7. Even if the faults were detected in time, it would not be possible to avoid the power from the sub-cycle overvoltage to pass through the bypass switch before next zero crossing since the SCR would continue to conduct even if it was turned off.

Figure 5: Transient occurring on grid Figure 6: Sub-cycle overvoltage  
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In other situations where transients are decreasing towards zero, or during a sub-cycle under voltage, the inverter is immediately able to support the load avoiding the grid fault to affect the connected load.

The power generated by the inverter is not reversed through bypass to utility mains since bypass is operating as one directional conductor during the operation mode of eConversion Mode.

#### Upstream and Downstream Short

In ECO Mode the static bypass switch is operating as a bidirectional conductor able to conduct current to and from the load. This is not the case when operating in eConversion Mode. In eConversion an advanced method of bypass operation is used (patent pending 2012/0181871). This method enables the UPS to handle occurring upstream short as illustrated in Figure 8 where a short forces bypass input to zero. From the bypass current it can be seen that no current is conducted upstream, and the inverter voltage shows that the load is continually supplied. The upstream short occurs at 180 degrees and in a no load situation, since this is one of the most difficult situations for the UPS to handle.

In Figure 9 the same test is conducted with an UPS in ECO Mode. In this case the inverter output voltage is forced to zero from the occurring upstream short until next zero crossing where both bypass SCR's are able to stop conducting. In this period, the inverter tries to take over from bypass but the inverter current is conducted from the inverter through bypass to the upstream short and therefore not powering the load, and in this case not able to clear the upstream fault.

The resonance observed on bypass and inverter voltage, together with bypass current, is a result of the capacitance and inductance present on the grid and

connected systems.

Figure 7: Upstream short when systems in eConversion Mode 0% load short at 180 degrees.

Blue bypass V, yellow bypass I, red inverter V,

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Figure 8: Upstream short when systems in ECO Mode 0% load short at 180 degrees.

Blue bypass V, yellow bypass I, red inverter V,

In a case with a downstream short ECO Mode and eConversion Mode have different reaction patterns compared to double conversion. A system in double conversion, which is experiencing a downstream short, will based on the large inverter current transfer to static bypass. This ensures the largest possible current resulting in a rapid clearing of a downstream protective device.

An UPS operating in ECO Mode or eConversion Mode is supplying the load through bypass. This enables a high immediate current to clear the downstream protective device, but based on an occurring output voltage waveform fault, the system will transfer to inverter operation. If the waveform fault is not cleared before transferring to inverter operation, the downstream current is limited to the abilities of the inverter. If this is not sufficient, the UPS returns to bypass operation increasing the abilities to clear downstream.

If the downstream short is cleared before transferring to inverter operation, then eConversion Mode and ECO Mode have supplied the load with the best protection. If the downstream short is not cleared when in bypass operation then the transfer process from bypass to inverter operation and then back to bypass take more time than it would in a system in double conversion and is therefore less ideal.

eConversion is a class 1 operation

Based on possible outage situations the UPS when operating in eConversion is able to react as a class 1 system according to ICE 62040-3. As illustrated in Figure 10 the system output voltage is kept within limits of a class 1 system rating.

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Figure 9: In eConversion mode the UPS is rated as a class 1 system giving zero breaks transfer at power

outage (ICE 62040-3), the same category as double conversion  
PFC Off and Contactor Open

In order to decrease UPS power consumption when operating in eConversion Mode, the PFC rectifier is turned off. The system DC bus powering fans, controller, battery charger, etc. is being powered through the inverter using power from bypass.

In Figure 11 the power flow in ECO Mode is shown and the inverter is not active in charging the DC bus. Figure 12 illustrates the power flow in eConversion Mode where the DC bus is being powered from the inverter via bypass. This allows for increased system efficiency while maintaining all system functionalities. As a consequence of this, each transfer from eConversion Mode to double conversion must first rely on power from the batteries until the UPS has closed its input contactors and can draw power from the grid. This will typically result in batteries partly supplying the load for 20 seconds (adjustable) during ramp-in to mains power and will have little or no effect on the charge state of the batteries. However, this could have an effect on the battery life cycle if eConversion Mode is chosen in an installation where transfer to inverter operation is often required.

Conducting many small discharges on a battery installation can decrease the overall life expectancy of the installed batteries and is one of the reasons for the recommendation to only use eConversion Mode in installations supplied by a reliable power grid of reasonable good quality requiring few transfers from eConversion Mode to inverter operation.

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AC in

Bypass Swit

AC in Load

ch

DC/DC

PFC Rectifier

Maybe on to

allow battery

recharge

## Battery Inverter

high and even though the inverter is supporting the output voltage shape, it is not controlling the harmonics. The next figure (Figure 14) illustrates the bypass current drawn by the same SMPS load, but with harmonic compensation enabled. Note that the bypass current is now more sinusoidal shaped. The inverter is working to decrease the harmonics currents generated by the load giving a unique shape of the inverter current.

The harmonics content on bypass when enabling harmonic suppression is significantly decreased as can Figure 10: In ECO Mode the DC bus is being charged through the PFC to allow the batteries to be charged.

## Battery

Figure 11: In eConversion Mode the DC bus is being charged through the inverter to allow the batteries to be charged.

## Harmonic Compensation and Power Factor

When operating in ECO Mode the bypass utility will receive whatever power factor and harmonic currents the load generates. This is not the case when operating in eConversion Mode. Here the inverter operating in parallel with bypass is able to correct system power factor ensuring power drawn from mains at unity power factor. It is further possible to select a suppression of harmonic currents. This enables the inverter to operate as an active filter removing most of the harmonics current content of the connected load. In practice the system is able to suppress 3', 5', and 7' harmonics since these are typically carrying the significantly largest part of the total harmonic content.

Figure 13 illustrates a SMPS load connected to a UPS in eConversion Mode with harmonic suppression disabled.

The harmonic content of the bypass current is be seen in Table 1.

This shielding of the harmonic currents generated by the load and correction of power factor protects the utility or generator power source.

Suppression of harmonic currents is by default enabled but can, though it is not recommended, be turned off if required. Correction of power factor is by default on and can only be disabled by exiting eConversion Mode and transferring to ECO Mode.

Operation of loads where the total load is generating power (regenerative loads) is not supported by eConversion.

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Figure 12: eConversion with Harmonics Compensation disabled  
Situation with 60% SMPS load applied on at 4-wire 400 V 50 Hz system.  
Blue Inverter V, Red Inverter I, Yellow Bypass V, Green Bypass I

Figure 13: eConversion with Harmonics Compensation enabled  
Situation with 60% SMPS load applied on at 4-wire 400 V 50 Hz system.  
Blue Inverter V, Red Inverter I, Yellow Bypass V, Green Bypass I

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Table 1: Harmonic content in ECO Mode compared to eConversion when 60% SMPS load is applied

ECO Mode	eConversion Mode
Harmonic Input current	
harmonics [%]	
Input current	
harmonics [%]	
H3	40 2.50
H5	21 2.25
H7	7 1.07

#### Efficiency in eConversion Mode

Given that the reason for choosing eConversion Mode as operation mode is to decrease power consumption of an installation, it is interesting to compare the loss related to the different modes of operation. Besides saving energy on the UPS as an isolated system, an additional energy saving can in some cases be achieved on UPS cooling. The evaluation of this is much more individual since it depends on the installation and chosen method of cooling (e.g. air- conditioning, ventilation) and must therefore be evaluated for the specific installation.

In Figure 15 an efficiency plot of a 200 kVA UPS in double conversion, ECO Mode and eConversion Mode can be observed. With 50% resistive load there is a gain in efficiency from 96.37% in double conversion to 98.64% in eConversion Mode. This is a significant improvement of the UPS efficiency by up to 2.27%. The efficiency improvement in eConversion mode is

dependent on the load type applied to the UPS. The more the inverter has to compensate the load current the less improvement in efficiency will be achieved compared to double conversion. For further details regarding applied load and the resulting eConversion efficiency refer to appendix A.

Figure 14: Efficiency plot data derived from Table 2 Galaxy VM

99

98

97

96

Double

conversion

eConversion

94

93

92

20 40 60 80 100 120

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Table 2: Derived from UL test report (10-23-2014) (IEC 62040-3: 2011-3 2nd Edition).

Double

conversion

eConversion eConversion vs

Double conversion

Load [%] Efficiency [%] Efficiency [%] Efficiency gain [%]

Galaxy VS

50 kW 400V

25 96.4 98 1.6

50 97 98.9 1.9

75 97 99.1 2.1

100 96.7 99.3 2.6

Galaxy VM

200 kVA 400V

25 93.3 94.5 1.2

50 96.4 98.6 2.2

75 96.2 99 2.8

100 95.7 99.1 3.4

Galaxy VL

500 kW 400V

25 96.6 98.4 1.8

50 97.1 99 1.9

75 96.9 99.2 2.3

100 96.6 99.3 2.7

Galaxy VX

1250 kW 400V

25 95.6 97.9 2.3

50 96 98.8 2.8

75 95.7 98.9 3.2

100 95.2 99 3.8

Galaxy VXL

1250 kW 400V

25 96.9 98.7 1.8

50 97.3 99.2 1.9

75 97.4 99.4 2.0

100 96.9 99.4 2.5

In average, a gain of 2-3% efficiency is observed in Galaxy V series when using eConversion rather than double conversion

#### Output Quality Settings

When operating in eConversion Mode the system output voltage is following the bypass voltage. To increase system transfer speed when a bypass waveform fault occurs, the bypass voltage fault detector has increased sensitivity. By this, a smaller waveform fault on bypass for a system in eConversion Mode will result in a transfer to double conversion.

To further improve the system ability to trace the bypass source and avoid transfers from eConversion Mode to double conversion due to small phase changes, the system frequency slew rate is defaulted to maximum level when in eConversion Mode. When the UPS returns to double conversion the user adjusted values are used.

A system which is selected to operate in eConversion Mode should be configured with the widest possible range of operation. Based on this, the FSE must set the system voltage limits and frequency limits as high as possible for the given installation.

#### User Interface

eConversion Mode can be enabled and configured by the customer without the need of an FSE and UPSTuner. The user interface is almost the same as for ECO Mode, only with the addition of one parameter, the 'eConversion Harmonics Compensator.'

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### Setup and configuration

The following parameters can be configured for eConversion Mode:

- High Efficiency Mode: Selects which high efficiency mode to be used. Value can be 'None,' 'ECO Mode,' or 'eConversion.' Must be set to eConversion Mode.
- High Efficiency Mode Setup: See description in section 'ECO Mode.'
  - eConversion Harmonics Compensator: Setting to enable and disable the harmonic compensator feature available in eConversion Mode.

### Operation

When the UPS is in eConversion Mode, this will be indicated as both the system and the UPS operation mode in the UPS display and UPSTuner.

The UPS mimic diagram will indicate eConversion Mode as in Figure 16.

Figure 15:

Mimic diagram indication of eConversion Mode.

### Operation Conditions and Behavior

The UPS will transfer to eConversion mode only if it is enabled via a setting, the UPS has been in inverter operation for minimum 10 seconds and the bypass utility is within the configured tolerances. Furthermore, the UPS will evaluate the operational status of the battery and the power modules to determine if the conditions allow for operating in eConversion before transferring.

Should the operation conditions change while in eConversion, so that they are no longer optimal for this operation mode, the UPS will automatically transfer back to double conversion. This would for example be the case if the bypass utility becomes out of tolerance or the UPS output is overloaded. The UPS will automatically

transfer back to eConversion again when the conditions allow for it.  
 If the UPS continuously transfers back and forth between eConversion and inverter operation, it indicates that the conditions are not optimal for operating in eConversion, and therefor eConversion mode will automatically be disabled by the system and the user will be notified via an alarm. The user can then manually re-enable eConversion again.

It is also possible to configure an input contact on the UPS to disable eConversion mode when the input contact is activated.

This way an external system can temporarily prevent eConversion mode without disabling it permanently if there are situations where this is desired.

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Appendix A

eConversion efficiency compared to leading load

Figure 16: System efficiency related to leading load PF 1.00 0.95 0.90 0.80.

eConversion efficiency compared to lagging load

Figure 17: System efficiency related to lagging load PF 1.00 0.95 0.90 0.80.

Galaxy VM eConversionEfficiency

Leading PF Load

99.00

98.00

97.00

96.00

1.0 Lead

0.95 Lead

0.90 Lead

0.80 Lead

95.00

94.00

20 40 60 80 100

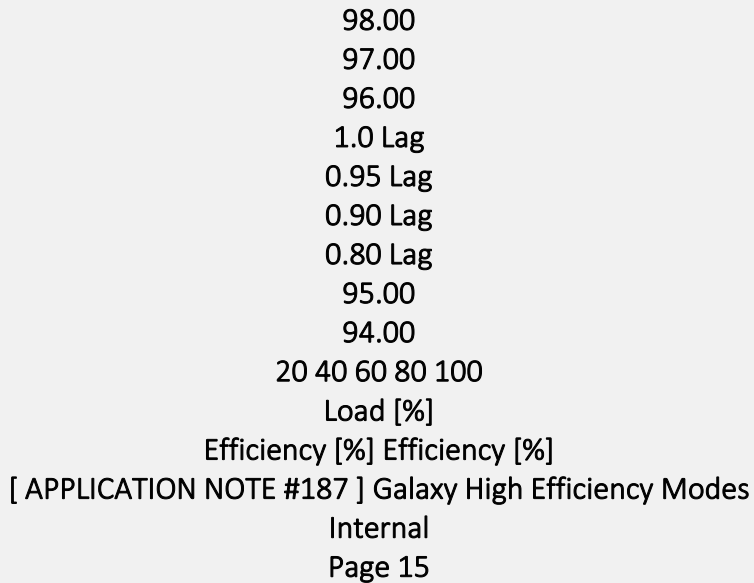
Load [%]

Galaxy VM eConversionEfficiency

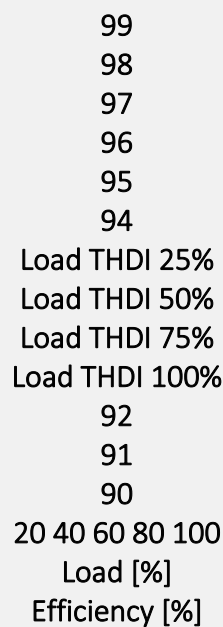
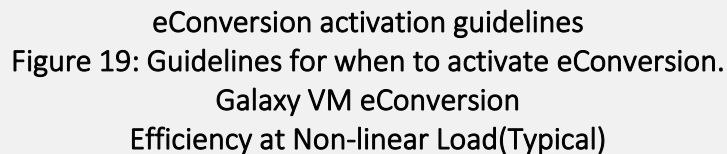
Lagging PF Load

100.00

99.00



eConversion efficiency compared to harmonic load  
Figure 18: System efficiency related to harmonic content.  
Appendix B



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[Target Audience](#)

This document is intended to address Design Firms, End Users, Engineering, Operations and Maintenance, Consultants, Specifiers, EPCs and Service teams, and other qualified personnel.

[Objective](#)

To understand how EcoStruxure Power for Railway can help improve electrical safety, power reliability and sustainability across Railway and Urban Transportation facilities. The document deep dives into the various facilities across Railway and Urban Transportation to address specific customer pain points.

[Purpose of the Document](#)

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[SECTION 1: Introduction to the Railway  
and Urban Transportation Market](#)

Introduces the market, trends, segmentation, facilities and key challenges of the Railway and Urban Transportation industry.

## SECTION 2: How EcoStruxure Power Can Support the Railway and Urban Transportation Segment

Describes the solutions that EcoStruxure Power provides for the industry with an overview of applications along with typical electrical and digital architectures.

## BIBLIOGRAPHY

Contains useful documents and links to find out more about capabilities and applications across the industry.

## SECTION 3: Digital Solutions and Services across the Facilities

Provides information regarding the different types of facilities within the Railway and Urban Transportation industry, and outlines customized solutions along with electrical and digital architectures:

1. Overhead Lines
2. Traction Substations
3. Auxiliary Powers
4. Passenger Stations
5. eBus Depots
6. Tunnel Systems
7. Depots and Workshops
8. Control Center

## SECTION 5: Customer Stories

Discover our customer stories across the globe to see how Schneider Electric has helped to overcome Railway challenges and pain points.

## SECTION 4: Design considerations

Details the recommendations and guidelines to be considered for deploying digital architecture for Railway and Urban Transportation. Provides details of key system considerations across communications, data, time and cybersecurity.

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## WHY READ

## THIS SECTION?

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The objective of this section is to:

- Introduce the Railway and Urban  
Transportation market growth,  
trends and segmentation

- List the different types of  
facilities across Railway & Urban  
transportation

- Present the industry challenges  
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 Electrification of Public  
 Transport Fleets  
 +27.2% CAGR YoY growth  
 of eBus market (2019-2027).  
 Railway and Urban Transportation Market Outlook  
 Market growth: Rail is a key driver for country's sustainable economic development  
 Sources  
 Maintenance Savings  
 Up to 40% savings  
 in maintenance if reliability  
 improvements are deployed  
 in an infrastructure.  
 Increased Rail  
 Traffic Growth  
 +2-3% per year  
 expected until 2030 for passenger  
 and freight  
 Acceleration  
 of Digital  
 Transformation  
 European Union invests  
 estimated €6.2B in EU grants  
 from CEF (Connecting Europe  
 Facility) as strategic investment  
 for transportation infrastructure.  
 Move towards NetZero  
 In 2019, UIC (International Union  
 of Railways) took the pledge  
 to achieve carbon neutrality  
 by 2050.  
 Most Preferred Public  
 Transportation

2/3rd of business travellers  
from UK to Europe prefer train  
travel, as do 77% of leisure  
passengers.

Sustainable

Urbanization

68% of the world's population  
will be urban by 2050 versus  
55% today.

43 megacities of more than  
10 million inhabitants by 2030

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in 2019 to Reach 935

Thousand Units by 2027, at a CAGR of 27.2%

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[maintenance-costs/](https://www.idcon.com/resource-library/leadership-in-maintenance/reliability-lowers-maintenance-costs/)

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[responsibility-pledge](https://uic.org/sustainability/energy-efficiency-and-co2-emissions/railway-climate-responsibility-pledge)

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Market trends

Railway and Urban Transportation Market Outlook

Increased demand for railways driven by urbanization

High-speed rail (HSR) has been set up in succession in various developed  
and developing countries (1).

Focus on increased energy efficiency to reduce  
carbon emissions

28 European UIC\* members have collectively committed to reducing  
CO2 emissions by 50% by 2030 (per passenger-km and per tonne-km) (2).

Massive investment in the digitalization of railway  
infrastructures

The size of IoT in Railway market is estimated to reach \$50.58 billion by  
2030, growing at a CAGR of 9.1% during 2023-2030 (3).

Protection of railway networks against cyber threats

Railway cybersecurity market is anticipated to reach USD 13.90 billion by  
the end of 2030 (4).

Sources

(1) <https://www.mdpi.com/2073-445X/11/10/1790>

(2) <https://uic.org/sustainability/energy-efficiency-and-co2-emissions/>

(3) <https://www.industryarc.com/Research/iot-in-railways-market-research-800191>

(4) <https://railmarketresearch.com/product/railway-cybersecurity-market-size-share-industry-analysis-forecast-to-2030/>

UIC\*: International Union for railways

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Railway and Urban Transportation Market Segmentation	
High-speed Main lines FreightCommuter	
• Long distances	
• Over 250 km/h	
• Medium-to-long distances	
• Scheduled service	
• Low or very low speed	
• Diesel fuel	
• Short distances and many stops	
• Low speed and high capacity	
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Railway and Urban Transportation Market Segmentation	
Metro Light Rail Buses Tramway	
• High frequency	
& capacity	
• Segregated from	
general roads	
• Lower capacity	
& speed	
• Operation in	
a street traffic	
environment	
• City buses stored	
& maintained in	
bus depots	
• Lower capacity	
& speed	
• Operation in	
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 Railway facilities  
 Railway and Urban Transportation Facilities  
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 Auxiliary power systems  
 Passenger stations  
 Depots &  
 workshops  
 Datacenter  
 Traction  
 substations  
 Control  
 center  
 Tunnel systems  
 Overhead  
 lines  
 Public  
 Auxiliary Power Systems  
 Comprehensive solution for a reliable  
 distributed signaling, telecom &  
 auxiliary power network:  
 • Power distribution  
 • Backup power  
 • Power quality  
 Passenger Stations

Integrated solution to supervise  
and control:

- Electromechanical systems  
(elevator, pumps, etc.)
  - HVAC
- Power distribution

• Security management

Depots & Workshops

Management of depot infrastructure  
including:

- Power distribution
- Process automation
  - Power quality

Datacenter

Datacenter infrastructure  
management:

- Backup power
- Cooling system and  
racks
- Power distribution
- Security management

Traction Substations

Comprehensive solution for  
reliable and safe electrification of  
railway lines:

- Power distribution for traction  
system
- Control and protection system
  - Backup power
  - Power quality

Central management and  
maintenance of railway  
infrastructure:

- Power
- Passenger stations
  - Tunnel
- Depot & workshops

Control Center

Integrated solution to  
supervise and control:

- Ventilation
- Power distribution
- Fire management

Tunnel Systems

Overhead Lines  
 Comprehensive solution  
 for safe electrification of  
 the catenary system:  
 • Power distribution for  
   catenary  
   • Control system  
 Typical Requirements of a Railway Line  
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lines  
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 auxiliary power network:
 

- Power distribution
- Backup power
- Power quality

 Underground  
 Passenger Stations  
 & Tramway Stops  
 Integrated solution to  
 supervise and control:
 

- Electromechanical  
systems (elevator,  
pumps, etc.)
- HVAC & ventilation
- Power distribution
- Security management

 Depots & Workshops  
 Management of depot  
 infrastructure including:
 

- Power distribution
- Process automation
- Power quality

 Datacenter  
 Datacenter infrastructure  
 management:
 

- Backup power
- Cooling system and racks
- Power distribution
- Security management

 Traction Substations  
 & Overhead Lines  
 Integrated solution for reliable and  
 safe electrification of urban

transportation lines:

- AC power distribution for traction system
- Integrated AC/DC control system
  - Backup power
  - Power quality

Central management and maintenance of urban

transportation infrastructure:

- Power
- Passenger stations
  - Tunnel
- Depot & workshops

Control Centers

Integrated solution to supervise and control:

- Energy distribution
- Microgrid management
- Charging infrastructure
- Asset management

eBus Depots

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An industry focused on the best possible passenger experience  
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How to enable reliable  
electrification to avoid  
downtime, increase  
availability and improve  
operational efficiency for  
rail services?  
How to improve safety  
and comfort across the  
entire railway  
infrastructure to provide  
the best passenger  
experience?  
How to adapt  
digitalization by  
maximizing the value  
from rail assets & ensure  
cybersecurity during the  
entire lifecycle?  
How can we contribute  
to the decarbonization  
of transportation market,  
reducing energy  
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The objective of this section is to:

- Describe how the Schneider Electric value proposition can support the industry and address the challenges and pain points
- Explain how EcoStruxure Power applications can support at facility level

- Recommend digital architectures for the infrastructure
- How EcoStruxure Power  
Can Support the Railway  
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 Decarbonization Digitalization Safety and Comfort

Reliable  
 Electrification  
 Improve reliability of  
 electrical  
 infrastructure  
 Enhance safety and  
 comfort in passenger  
 stations and tunnels  
 Operate centrally and  
 maintain infrastructure  
 efficiently  
 Reduce energy  
 consumption  
 and carbon footprint

Schneider Electric Solutions to Address Railway Industry Challenges

Four pillars to meet your challenges and provide the best passenger experience

This guide describes the solutions developed by EcoStruxure Power to address these four pillars.

- Provide automatic power restoration and model digital twin for traction substation system, passenger stations and tunnel systems along the tracks
- Modernize aging electrical distribution infrastructure  
 Enable automation control to improve:
- Safety in tunnels in case of emergency
- Comfort of passengers in the stations

- Operate and maintain the electrical infrastructure, passenger stations, tramway stops, tunnels facilities and depots and workshops centrally
- Break silos and improve effective collaboration between operator's
- Mitigate OT cybersecurity risks
- Improve energy efficiency in passenger stations
  - Optimize microgrids for passenger stations and depots
- Electrify bus depots. Manage and maintain the installation
  - Provide sustainability consulting for renewable energy sourcing

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Why consider EcoStruxure Power solutions for your infrastructure?

## Schneider Electric Solutions to Address Railway Industry Challenges

EcoStruxure Power helps deliver an end-to-end digital solution for efficient, reliable and sustainable Railway and Urban Transportation.

From Traction substations to passenger stations

From electrical design to operations and maintenance,

Our comprehensive digital solution, enhanced by the Electrical Distribution Digital Twin enables operations with higher productivity

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Discover EcoStruxure Power applications to support the challenges and pain points of the Railway industry:

EcoStruxure Power Digital Applications for Railway Industry

List of applications by pillar and by sub-segment

Summary of products, Edge Control, apps and services required by application

Summary for Products

EcoStruxure Power Applications for Railway

and Urban Transportation  
 Summary for Edge Control, Apps and Services  
 Public EcoStruxure Power Applications for Railway and Urban Transportation  
 Public Summary for Connected Products  
 Public Summary for Edge Control, Apps and Services  
 More applications  
 Public Summary for Edge Control, Apps and Services  
 Back to previous applications  
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 Our end-to-end digital solutions and services to digitalize your electrical distribution  
 Reference Digital Architecture for Railway and Urban Transportation  
 Public Example of Digital Architecture  
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The objective of this section is,  
for each type of facility, to:

- Introduce the facility
- Review EcoStruxure Power value propositions and the associated applications for this facility
- Provide reference electrical and digital architectures

EcoStruxure Power

Digital Solutions and Services

for:

à Overhead Lines

à Traction Substations

à Auxiliary Power Systems

à Passenger Stations

à eBus Depots

à Tunnel Systems

à Depots and Workshops

à Control Center

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The objective of this section is to:

- Introduce overhead lines
- Review EcoStruxure Power value propositions and the associated applications for overhead lines
- Provide reference electrical and digital architectures

EcoStruxure Power

Digital Solutions and Services

for:

à Overhead Lines

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What is it?	
Introduction to Overhead Lines	
The Overhead Line (OHL) system works as a distribution network from the traction	
substation to provide power	
to the moving rolling stock.	
Electric trains collect their current from one of the following OHL devices:	
Transportation means can also be supplied by:	
• A third rail	
• Ground-level power supply	
• Batteries	
• Electromagnetic induction	
Alternative electrical power transmission schemes	
Pantograph Bow collector Trolley pole	
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Contact wire

Catenary/

messenger wire

Mast

Connection

to the rail

OHL disconnectors

How does it work?

Introduction to Overhead Lines

The overhead lines are located over the rail tracks and constituted of one or more:

- Contact wires supported by the catenary/messenger wires (in the case of electric trains)
- Overhead rails (in the case of rigid catenaries, like in metro and tunnels).

The overhead lines are fed with electrical energy from the traction substations which are located at regular intervals.

The line is sectioned using disconnectors located at periodic intervals to:

- Allow the isolation of the sections in case of electric faults
  - Allow maintenance tasks
  - Separate different electrical zones

The overhead line is powered using high voltage electrical power:

- 1.5 - 3.5 kV in DC
- 25 kV in AC

Typically:

- Railway networks are serviced by AC power
  - Urban Transportation networks are serviced by DC power
- Rails are typically used as the return path for current, through the steel wheels of the train.

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Main components of the electrical architecture solution	
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## SECTION 5 – Customer Stories

### 2. Operational Management

The Edge Control solution enables the local and remote operation of the disconnectors.

### 3. Analysis & Optimization

Cloud-based services provide recommendations for predictive power asset maintenance.

#### 1. Primary Equipment

This equipment is used to connect / disconnect the overhead line feeds coming from the traction substations. It consists of a distributed solution based on a drive controller per disconnector and a central acquisition cabinet capable of managing several controllers.

#### EcoStruxure Power Value Proposition

Apps,  
analytics,  
and services

Edge  
Control  
Connected  
products

Voltage  
detector  
Control

Unit  
Drive  
controller

for Overhead Lines

Local

HMI

AVEVA

System Platform

EcoStruxure

Power Operation

Cloud-Based Advisor Services  
for asset management services

Our solution to control and supply energy to overhead lines

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Reliable

Electrification

Improve reliability of electrical infrastructure

Electrical Distribution

Monitoring and Alarming

Power Event Analysis

Overhead Line Protection and Automation

Safety and Comfort

Enhance safety and comfort in passenger stations and tunnels

Guided Procedures Through Extended Reality

Digitalization

Operate centrally and maintain infrastructure efficiently

Asset Performance

Electrical Distribution

Monitoring and Alarming

Power Event Analysis

Decarbonization

Reduce energy consumption and carbon footprint

Specific pillars for overhead lines

## EcoStruxure Power Value Proposition

EcoStruxure Power provides applications to support the challenges of Overhead Lines for Railway

and Urban Transportation with the following pillars:

Overhead Line Protection

and Automation

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Our Digital Solutions and Services: Applications Overview

■■■ Essential ■■ Recommended ■ Desirable Click on the blue links to have more  
information

è Provide real-time status of the electrical distribution system

è Help identify anomalies and notify the right personnel

è Aggregate onboard alarm data in an easy-to-understand way

è Take advantage of native integration of intelligent electrical devices

Reliable Electrification

Electrical Distribution

Monitoring and

Alarming

Power Event

Analysis	
è Provide a user-friendly graphical tool to simplify and save time in event analysis	
è Provide an aggregated view of events in the same dashboard	
è Enable root cause analysis	
Reliable Electrification	
è Provide distributed control and supervision of overhead (catenary)	
line disconnectors	
Reliable Electrification	
Overhead Line	
Protection	
and Automation	
Guided Procedures	
Through XR	
è Use Extended Reality to perform step-by-step guidance	
è Benefit from “X-ray” vision and virtually overlaid contextual asset and site information,	
live data, events and alarms	
è Take advantage of remote collaboration	
Safety and Comfort	
Asset Performance	
è Make asset health visible across the entire system	
è Streamline inspections using continuous asset health monitoring	
è Optimize maintenance planning with analytics and expert advice	
Digitalization	
■	
■	
■ ■ ■	
■ ■	
■	
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 Reference Electrical and Digital Architectures  
 Typical electrical architecture Reference digital architecture  
 Find the Schneider Electric products necessary  
 to implement the selected applications.  
 Then find their location in the electrical  
 architecture.  
 Find how the products, software  
 solutions and cloud services are  
 connected in the digital architecture.  
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The objective of this section is to:

- Introduce traction substations
- Review EcoStruxure Power value propositions and the associated applications for traction substations
- Provide reference electrical and digital architectures EcoStruxure Power Digital Solutions and Services for:

à Traction Substations

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What is it?

## Introduction to Traction Substations

- Electrical Traction Substations are responsible for supplying trains with electrical energy.
- These facilities manage approximately 75% of the electricity consumption of the entire railway system
- They have a direct impact on the reliability and punctuality of railway traffic.

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How does it work?

Introduction to Traction Substations

Energy incomers Traction  
transformers

Feeders

Auxiliary  
systems

The Traction Substations are located at regular intervals (depending on AC or DC systems)  
along the railway.

Their main elements are energy incomers, traction transformers, rectifiers (for DC only),  
feeders and auxiliary systems.

Traction transformers and rectifiers  
(the latter for DC configurations) convert

electrical parameters to the energy input  
needs of the traction system.

Auxiliary systems  
are necessary  
for the operation  
of the facility.

Feeders provide  
energy to the  
overhead line

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Two types of traction substations, depending on the type of traction

Introduction to Traction Substations

Overhead

Line

Railway

25kV

It is most common in Urban Transportation.

è Catenary supply voltage = 600V- 3.3kV

Railway Urban Transportation

Overhead  
Line  
Railway  
3.3kV  
0.6kV  
~

Type 1: Alternating Current Supply Type 2: Direct Current Supply

Traction  
Transformer  
Overhead  
Line  
Railway  
25kV  
50kV  
Feeder  
Energy Flow

This is most common in Railway.

è Catenary supply voltage = usually 25kV, sometimes 15kV

è Two electrical configurations, depending on the number of phases  
in the secondary of the traction transformer:

- 1x25 kV
- 2x25 kV

Comparison of Current Supplies

Public

Direct Current (DC) Alternating Current (AC)  
Supply

The overhead line is supplied with AC  
current with the following configuration:

- Single phase connected to the  
overhead line
- Current returns through a return path

Advantages

- Simple configuration. No need of  
intermediate transformer stations
- No need of feeder cable

Supply

The overhead line is supplied with AC current with  
the following configuration:

- One phase connected to the overhead
- The other phase connected to a feeder  
conductor

Phases are 180 degrees out of phase  
resulting in voltage up to 50 kV voltage.

Advantages

- Higher energy capacity
- Fewer traction substations needed  
(but requires more simple intermediate  
transformer stations)
- Reduced electromagnetic interferences

Single-phase System (1x25 kV) Two-phase System (2x25 kV)

Main Application

Urban transportation: metro, light rail, tramways

Catenary supply voltage

600V- 3.3kV

Supply

The traction system provides DC current to the  
overhead line.

The conversion to direct current requires the use of:

- Non-linear power electronic components  
(rectifiers),
- Three-winding voltage transformers
- Medium voltage feeder panels
- Electric protections specially adapted to this mode

Advantages

- Possibility to power a section with two sources  
in parallel
- Large installed base, making extensions easier  
if the rest of the line also uses DC current
- Better regulation of motor speed (before the  
advent of power electronics)

Main Application

Mainlines, high-speed lines

Catenary supply voltage

Usually 25kV, sometimes 15kV

Comparison of Current Supplies

Depending on the installation, the overhead line is powered with a Direct Current (DC) or  
Alternating Current (AC) system.

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Type 1 Substation	
(Majorly used in Railway)	
It demonstrates an alternating current (AC)	
design in a single/two-phase configuration, with	
an Intelligent Electronic Devices (IEDs)-based	
control system.	
Type 2 Substation	
(Majorly used in Urban Transportation)	
It demonstrates direct current (DC) design with a	
PLC-based control system.	
Public Main Components for Type 1 Alternating Current Supply Traction Substations	
Public Main Components for Type 2 DC Current Supply Traction Substations	
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2. Operational Management	
Real-time monitoring and control of power system status and	
identification of abnormal temperature, insulation faults,	
power disturbances, etc.	
The Power System Simulation Engine helps train operators	
and simulate the effects of switching or maintenance	
operations before the actual operation is performed	
3. Analysis & Optimization	
• Cloud-based predictive power asset maintenance with	
expert recommendation provided by our Schneider	
Electric service experts	
• Consulting Services including network and power quality	
audits	
• Augmented reality guidance for complicated or rarely	
1. Primary Equipment	
Protection, control, metering, UPS and other equipment used	
in Traction Substations. These are described in more detail in	
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analytics,	
and services	
Edge	
Control	
Connected	
products	
for Traction Substations	
Cloud-Based Advisor Services for asset management, data integrity	
and workforce empowerment with extended reality guidance	
Power quality	
meter	
Protection	

relay  
Circuit  
breaker  
Control  
unit  
Cooling  
DC protection  
relay  
(Third party)  
Gateway  
UPS Protection  
device  
Panel  
server  
Power  
quality  
solutions  
AVEVA  
System Platform  
EcoStruxure  
Power Automation  
System  
EcoStruxure  
Power Operation /  
Power Monitoring Expert Simulation Engine  
Our solution to control and supply energy to traction substations  
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 Specific pillars for traction substations  
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 EcoStruxure Power provides applications to support the challenges of Traction Substations  
 for Railway  
 and Urban Transportation, with the following pillars:  
 Reliable  
 Electrification  
 Electrical Distribution  
 Monitoring and Alarming  
 Capacity Management  
 Power Event Analysis  
 Power Quality Monitoring,  
 Correction, and Compliance  
 Advanced Protection and Automation  
 Safety and Comfort  
 Enhance safety and comfort in  
 passenger stations and tunnels  
 Continuous Thermal Monitoring  
 Guided Procedures Through  
 Extended Reality  
 Digitalization  
 Operate centrally and  
 maintain infrastructure efficiently  
 Backup Power Testing  
 Circuit Breaker Settings Monitoring  
 Asset Performance  
 Decarbonization  
 Reduce energy consumption  
 and carbon footprint  
 Effective Energy Accounting  
 Improve reliability of  
 electrical infrastructure  
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information

- è Provide real-time status of the electrical distribution system
- è Help identify anomalies and notify the right personnel
- è Aggregate onboard alarm data in an easy-to-understand way
- è Take advantage of native integration of intelligent electrical devices

Reliable Electrification

Capacity

Management

- è Visualize real-time or historical power system capacity
- è Monitor and trend circuit or equipment loading
- è Provide information for capacity planning

Reliable Electrification

Power Event

Analysis

- è Provide a user-friendly graphical tool to simplify and save time in event analysis
- è Provide an aggregated view of events in the same dashboard
- è Enable root cause analysis

Reliable Electrification

Power Quality

Monitoring, Correction,

and Compliance

- è Power Quality Monitoring and Compliance: Monitor persistent steady state and event-based disturbances to better understand and analyze power quality disturbances
- è Power Quality Correction: Correct over/under voltages, harmonics, etc.

Reliable Electrification  
Electrical Distribution  
Monitoring and  
Alarming  
Advanced Protection  
and Automation

- è Help provide protection and fault-tolerant automation schemes
- è Help maintain continuity of service in case of outages with an autonomous and fast response to events
- è Enable various protection schemes to help protect the electrical distribution system

Reliable Electrification



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■■■ Essential ■■ Recommended ■ Desirable Click on the blue links to have more information

#### Continuous Thermal Monitoring

è Monitor the temperature of busbar, cable, transformer, and withdrawable circuit breaker connections

è Help detect poor connections at an early stage

è Provide temperature alarming and reporting for fast response

#### Guided Procedures

##### Through XR

è Use Extended Reality to perform step-by-step guidance

è Benefit from “X-ray” vision and virtually overlaid contextual asset and site information, live data, events and alarms

è Take advantage of remote collaboration

#### Safety and Comfort

#### Safety and Comfort

#### Backup Power

##### Testing

è Automatically record key backup power test parameters such as run time, engine loading, exhaust and engine temperatures

è Perform automated backup power test reporting

#### Digitalization

##### Circuit Breaker

##### Settings Monitoring

è Compare current circuit breaker settings with commissioned settings

è Help detect inappropriate setting modifications periodically

è Provide information for capacity planning

#### Digitalization

##### Asset Performance

è Make asset health visible across the entire system

è Streamline inspections using continuous asset health monitoring

è Optimize maintenance planning with analytics and expert advice

#### Digitalization

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Effective Energy	
Accounting	
Identify areas for possible energy conservation measures:	
è Utility Bill Verification: Identify billing errors by comparison with a shadow bill	
è Cost Allocation: Allocate energy costs to terminals or departments for accurate billing	
è Power Factor correction: Mitigate harmonic effects and power quality issues	
Decarbonization	
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 Reference Electrical and Digital Architectures  
 Typical electrical architecture  
 Find the Schneider Electric products necessary  
 to implement the selected applications.  
 Then find their location in the electrical  
 architecture.  
 Find how the products, software  
 solutions and cloud services are  
 connected in the digital architecture.  
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 Type 1: Alternating Current (AC) Supply  
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 Public Typical Electrical Architecture for Traction Substations with AC Current Supply  
 Public Typical Electrical Architecture for Traction Substations with DC Current Supply  
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The objective of this section is to:

- Introduce auxiliary power systems
- Review EcoStruxure Power value propositions and the associated applications for auxiliary power systems

- Provide reference electrical and digital architectures

EcoStruxure Power  
Digital Solutions and Services  
for:

à Auxiliary Power Systems

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What is it?

Introduction to Auxiliary Power Systems

Auxiliary Power Systems are electrical distribution systems  
incorporated in the railway infrastructure to power loads that  
require electricity for their operation, such as:

- Interlocks and other signaling equipment
  - Track sensors
  - Point heaters
- Telecommunications equipment
  - Other technical buildings

They are particularly used in areas where it is not possible to find  
a regular supply of electricity.

è 25% of the total energy of the railway system is consumed by  
auxiliary power systems.

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How does it work?	
Introduction to Auxiliary Power Systems	
Many railway consumers are highly critical about the operations and safety of their infrastructure: the reliability of their power supply must be optimum.	
Power distribution loops, connected with two different sources, are used to improve availability of electrical energy.	
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Points (PSP)	
Functional Supply	
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Public Main Components of the Electrical Architecture for Auxiliary Power Systems	
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• Real-time monitoring and control of power system status	
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• The Power System Simulation Engine helps train	
operators and simulate the effects of switching or	
maintenance operations before the actual operation is	
performed.	
3. Analysis & Optimization	
• Cloud-based predictive power asset maintenance with	
expert recommendation provided by our Schneider	
Electric service experts	
• Consulting services including network and power quality	

audits

- Augmented reality guidance for complicated or rarely performed procedures

1. Primary Equipment

Protection, control, metering, UPS and other equipment used in Auxiliary Power Systems. These are described in more detail in the following pages

EcoStruxure Power Value Proposition

Apps,  
analytics,  
and services

Edge  
Control  
Connected  
products

Cloud-Based Advisor Services for asset management, data integrity and workforce empowerment with extended reality guidance for Auxiliary Power Systems

Power  
quality  
meter  
Protection  
relay  
Remote  
terminal  
unit  
Circuit  
breaker

Automatic  
transfer  
switch

UPS  
Power  
quality  
solutions

Panel  
server

Insulation  
monitoring  
device

Local  
HMI

AVEVA  
System Platform  
EcoStruxure

Power Operation /	
Power Monitoring Expert	
Our solution to control and supply energy to auxiliary power systems	
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Specific pillars for auxiliary power systems	
EcoStruxure Power Value Proposition	
EcoStruxure Power provides applications to support the challenges of auxiliary power	
systems for Railway	
and Urban Transportation with the following pillars:	
Reliable	
Electrification	
Electrical Distribution	
Monitoring and Alarming	
Capacity Management	
Power Event Analysis	
Power Quality Monitoring,	
Correction, and Compliance	
Power Source and Load Control	
Safety and Comfort	

Enhance safety and comfort in  
 passenger stations and tunnels  
 Continuous Thermal Monitoring  
 Guided Procedures Through  
 Extended Reality  
 Digitalization  
 Operate centrally and  
 maintain infrastructure efficiently  
 Backup Power Testing  
 Circuit Breaker Settings Monitoring  
 Asset Performance  
 Decarbonization  
 Reduce energy consumption  
 and carbon footprint  
 Basic Energy Awareness  
 Advanced Energy Performance  
 Energy and Environmental  
 Compliance  
 Effective Energy Accounting  
 Improve reliability of  
 electrical infrastructure  
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##### Our Digital Solutions and Services: Applications Overview

■■■ Essential ■■ Recommended ■ Desirable Click on the blue links to have more information

Capacity

Management

è Visualize real-time or historical power system capacity

è Monitor and trend circuit or equipment loading

è Provide information for capacity planning

Reliable Electrification

Power Event

Analysis

è Provide a user-friendly graphical tool to simplify and save time in event analysis

è Provide an aggregated view of events in the same dashboard

è Enable root cause analysis

Reliable Electrification

Power Quality

Monitoring, Correction,  
and Compliance

è Power Quality Monitoring and Compliance: Monitor persistent steady state and event-based disturbances to better understand and analyze power quality disturbances

è Power Quality Correction: Correct over/under voltages, harmonics, etc.

Reliable Electrification

Power Source

and Load Control

è Help isolate faults with relay automation and circuit breaker coordination

è Help preserve critical loads by automatically transferring to alternate power

è Help restore power quickly

è Get real-time visibility, automation and control of the entire electrical infrastructure

Reliable Electrification

■■

■■■

■■■

■■■

è Provide real-time status of the electrical distribution system

è Help identify anomalies and notify the right personnel

è Aggregate onboard alarm data in an easy-to-understand way

è Take advantage of native integration of intelligent electrical devices

Reliable Electrification

Electrical Distribution

Monitoring and

Alarming



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Continuous Thermal  
Monitoring

è Monitor the temperature of busbar, cable, transformer, and withdrawable circuit breaker  
connections

è Help detect poor connections at an early stage

è Provide temperature alarming and reporting for fast response

Guided Procedures  
Through XR

è Use Extended Reality to perform step-by-step guidance

è Benefit from “X-ray” vision and virtually overlaid contextual asset and site information,  
live data, events and alarms

è Take advantage of remote collaboration

Safety and Comfort  
Safety and Comfort

## Backup Power

### Testing

è Automatically record key backup power test parameters such as run time, engine loading, exhaust and engine temperatures

è Perform automated backup power test reporting

### Digitalization

#### Circuit Breaker

#### Settings Monitoring

è Compare current circuit breaker settings with commissioned settings

è Help detect inappropriate setting modifications periodically

è Provide information for capacity planning

### Digitalization

#### Asset Performance

è Make asset health visible across the entire system

è Streamline inspections using continuous asset health monitoring

è Optimize maintenance planning with analytics and expert advice

### Digitalization



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#### Our Digital Solutions and Services: Applications Overview

■■■ Essential ■■ Recommended ■ Desirable Click on the blue links to have more information

#### Effective Energy

#### Accounting

Identify areas for possible energy conservation measures:

- è Utility Bill Verification: Identify billing errors by comparison with a shadow bill
- è Cost Allocation: Allocate energy costs to terminals or departments for accurate billing
- è Power Factor correction: Mitigate harmonic effects and power quality issues

#### Decarbonization

#### Basic Energy

#### Awareness

- è Energy Monitoring: Increase awareness of energy usage by creating easy-to-understand graphical dashboards and reports from data
- è Cost Allocation: Identify "quick-win" opportunities for energy savings
- è Energy Efficiency Compliance: Report effectively about local/global energy and environmental building code compliance
- è Greenhouse Gas Reporting: Track and report emissions effectively to help cut carbon emissions

#### Decarbonization

#### Energy and

#### Environmental

#### Compliance

■■■

■■

■■

#### Advanced Energy

#### Performance

- è Energy Performance: Normalize energy data (e.g. with respect to building area) to give context. Analyze energy performance in context using KPIs
- è Energy Benchmarking: Compare energy usage with respect to other comparable facilities
- è Energy Modeling and Verification: Model the energy usage versus energy drivers

#### Decarbonization

■■

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Find the Schneider Electric products necessary  
to implement the selected applications.  
Then find their location in the electrical  
architecture.  
Find how the products, software  
solutions and cloud services are  
connected in the digital architecture.  
Public Typical Electrical Architecture for Auxiliary Power Systems  
Public Reference Digital Architecture for Auxiliary Power Systems  
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• Introduce passenger stations	
• Review EcoStruxure Power value	
propositions and associated	
applications for passenger	
stations	
• Provide reference electrical	
and digital architectures	
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à Passenger Stations	
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What is it?	
Introduction to Passenger Stations	
A passenger station is a railway or urban	
transportation facility where trains stop to load	
or unload passengers, freight or both.	
The stations themselves may be at ground	
level, underground, or elevated. Connections	
may be available to intersecting rail lines or	
other transport modes such as buses, trams,	
or other rapid transit systems.	
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How does it work? (1/2)

Introduction to Passenger Stations

It generally consists of a set of tracks flanked by passenger platforms.

Usually, it also accommodates buildings for services.

Platform

TrackStation building

The station building  
provides ancillary  
services as ticket  
sales, waiting  
rooms and the  
baggage/freight  
service.

For stations with a single-track line, a passing  
loop is usually provided to facilitate traffic  
movements.

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How does it work? (2/2)  
 Introduction to Passenger Stations  
 \* Closed Circuit Television  
 \*\* Heating, Ventilation, Air Conditioning  
 Telecom Ventilation CCTV\*/  
 Surveillance  
 Fire Detection Passenger  
 Information System  
 Public  
 Announcement  
 Access Control Escalator Elevator Power Supply  
 Drainage Lighting Emergency  
 Trip System  
 HVAC\*\*

A typical railway station consists of multiple technical systems that work in coordination in order to fulfill

the operational plan. These include:

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 Main components of the electrical architecture

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 Apps,  
 analytics,  
 and services  
 Edge  
 Control  
 Connected  
 products  
 for Passenger Stations  
 Cloud-Based Advisor Services for asset management, data integrity and  
 workforce empowerment with extended reality guidance  
 Automation  
 Server  
 EcoStruxure Power Value Proposition  
 2. Operational Management  
 Edge Control for all systems such as elevators,  
 escalators, lighting, HVAC, drainage, ventilation, etc.

These systems can be:

- Option 1: centrally controlled (from the Control Center) using Supervisory Control and Data Acquisition (SCADA)
- Option 2: locally controlled using onsite HMIs or mobile apps

A software interface is used to exchange the control perimeter between the local passenger station and the Control Center.

### 3. Analysis & Optimization

- Cloud-based predictive power asset maintenance with expert recommendation provided by our Schneider Electric service experts
- Consulting services including network and power quality audits
- Augmented reality guidance for complicated or rarely performed procedures

#### 1. Primary Equipment

Protection, control, metering, UPS and other equipment used in passenger stations. These are described in more detail in the following pages

AVEVA

System Platform

EcoStruxure

Power Operation /

Power Monitoring

Expert

EcoStruxure

Building

Operation

Protection

relay

Remote

terminal unit

Circuit

breaker

Safety

control unit

RIO

drop

Control

unit

Power

quality meter

Protection  
device  
UPS Power quality  
solutions  
Automatic  
transfer switch  
VSD  
Energy  
meter  
Panel  
server  
Cooling  
Local  
HMI

Our solution to control and supply energy to passenger stations

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Specific pillars for passenger stations

EcoStruxure Power Value Proposition

EcoStruxure Power provides applications to support the challenges of Passenger Stations for

Railway  
and Urban Transportation, with the following pillars:

Reliable

Electrification

Electrical Distribution

Monitoring and Alarming

Capacity Management

Power Event Analysis

Power Quality Monitoring,

Correction, and Compliance

Power Source and Load Control

Safety and Comfort

Enhance safety and comfort in  
passenger stations and tunnels

Continuous Thermal Monitoring

Guided Procedures Through

Extended Reality

Digitalization

Operate centrally and  
maintain infrastructure efficiently

Backup Power Testing

Circuit Breaker Settings Monitoring

Asset Performance

Decarbonization

Reduce energy consumption  
and carbon footprint

Basic Energy Awareness

Advanced Energy Performance

Advanced Microgrid

Energy and Environmental

Compliance

Building Automation

Effective Energy Accounting

Improve reliability of  
electrical infrastructure

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Our Digital Solutions and Services: Applications Overview	
■■■ Essential ■■ Recommended ■ Desirable	Click on the blue links to have more
information	
Capacity	
Management	
è Visualize real-time or historical power system capacity	
è Monitor and trend circuit or equipment loading	
è Provide information for capacity planning	
Reliable Electrification	
Power Event	
Analysis	
è Provide a user-friendly graphical tool to simplify and save time in event analysis	
è Provide an aggregated view of events in the same dashboard	
è Enable root cause analysis	
Reliable Electrification	
Power Quality	
Monitoring, Correction,	
and Compliance	
è Power Quality Monitoring and Compliance: Monitor persistent steady state and event-	
based disturbances to better understand and analyze power quality disturbances	
è Power Quality Correction: Correct over/under voltages, harmonics, etc.	
Reliable Electrification	
Power Source	
and Load Control	
è Help isolate faults with relay automation and circuit breaker coordination	
è Help preserve critical loads by automatically transferring to alternate power	
è Help restore power quickly	

è Get real-time visibility, automation and control of the entire electrical infrastructure

Reliable Electrification

■■■

■■■

■■■

■■■

è Provide real-time status of the electrical distribution system

è Help identify anomalies and notify the right personnel

è Aggregate onboard alarm data in an easy-to-understand way

è Take advantage of native integration of intelligent electrical devices

Reliable Electrification

Electrical Distribution

Monitoring and

Alarming

■■■

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■■■ Essential ■■ Recommended ■ Desirable Click on the blue links to have more information

Continuous Thermal  
Monitoring

è Monitor the temperature of busbar, cable, transformer, and withdrawable circuit breaker connections

è Help detect poor connections at an early stage

è Provide temperature alarming and reporting for fast response

Guided Procedures

Through XR

è Use Extended Reality to perform step-by-step guidance

è Benefit from “X-ray” vision and virtually overlaid contextual asset and site information, live data, events and alarms

è Take advantage of remote collaboration

Safety and Comfort

Safety and Comfort

Backup Power

Testing

è Automatically record key backup power test parameters such as run time, engine loading, exhaust and engine temperatures

è Perform automated backup power test reporting

Digitalization

Circuit Breaker

Settings Monitoring

è Compare current circuit breaker settings with commissioned settings

è Help detect inappropriate setting modifications periodically

è Provide information for capacity planning

Digitalization

Asset Performance

è Make asset health visible across the entire system

è Streamline inspections using continuous asset health monitoring

è Optimize maintenance planning with analytics and expert advice

Digitalization



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Effective Energy

Accounting

Identify areas for possible energy conservation measures:

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è Power Factor correction: Mitigate harmonic effects and power quality issues

Decarbonization

Basic Energy

Awareness

è Energy Monitoring: Increase awareness of energy usage by creating easy-to-  
understand graphical dashboards and reports from data

è Cost Allocation: Identify "quick-win" opportunities for energy savings

Decarbonization

è Energy Efficiency Compliance: Report effectively about local/global energy and  
environmental building code compliance

è Greenhouse Gas Reporting: Track and report emissions effectively to help cut carbon  
emissions

Decarbonization

Energy and

Environmental

Compliance

■■■

■■



## Advanced

### Microgrid

è Enhance power system reliability, despite grid instability often resulting from powerful storms and grid unavailability

è Reduce carbon emissions and optimize cost efficiency by leveraging Distributed Energy Resources (DERs)  
Decarbonization



## Advanced Energy

### Performance

è Energy Performance: Normalize energy data (e.g. with respect to building area) to give context. Analyze energy performance in context using KPIs

è Energy Benchmarking: Compare energy usage with respect to other comparable facilities

è Energy Modeling and Verification: Model the energy usage versus energy drivers  
Decarbonization



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■■■ Essential ■■ Recommended ■ Desirable

Building

Automation

è Monitor and control the electromechanical systems present in the passenger station

è Automate processes within the passenger station

è Implement operational and emergency scenarios

Decarbonization

■■■

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Introduction

Reference Electrical and Digital Architectures

Typical electrical architecture

Find the Schneider Electric products necessary  
to implement the selected applications.

Then find their location in the electrical  
architecture.

Typical digital architecture

Find how the products, software  
solutions and cloud services are  
connected in the digital architecture.

Railway	
Urban Transportation	
Railway and Urban Transportation	
Public Typical Electrical Architecture for Passenger Stations (Railway)	
Public Typical Electrical Architecture for Passenger Stations (Urban Transportation)	
Public Reference Digital Architecture for Passenger Stations (Railway and Urban Transportation)	
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The objective of this section is to:	
• Introduce eBus depots	
• Review EcoStruxure Power value	
propositions and the associated	
applications for eBus depots	
• Provide reference electrical	
and digital architectures	
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for:

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- What is it?

Introduction to eBus Depots

An eBus depot is a facility specifically designed for the maintenance, charging, and storage of electric buses (eBuses).

Electricity is stored on board

In this document, we will focus on reference architectures applied to use cases where electrical energy is stored on board.

Electricity is fed continuously from an external source

The majority of buses storing electricity are battery electric buses, in which the electric motor obtains energy from an on-board battery.

When electricity is not stored on board, it is supplied by contact with outside power sources.

For example, using:

• Overhead lines (e.g., trolleybus)	
• Non-contact conductors on the ground (e.g., OLEV = online electric vehicles)	
Two types of e-buses	
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Two types of electrical supply for buses with battery	
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The supply of electrical energy to the bus can be carried out with the following strategies, which can be combined:	
Charging along the way	
Mainly installed at bus stops, they allow a quick charge of energy during the time the	

bus is stopped at  
the bus stop.

Once the daily commute has  
been completed, the bus will  
return to the storage facility  
where it will be connected to  
the energy charging system  
until it must leave again to  
continue with the scheduled  
routes.

Power supply in the depot areas

The predictability of bus arrival and departure times is very important: It is necessary to  
optimize the charging

process to enhance the operating conditions.

In this document, we will focus on reference architectures applied to use cases  
where charging is done in depot areas.

The energy charge will therefore depend on the  
charger's power and the available charging time.

è Charging time: several hours

è Power involved: 50-200 kW

They are therefore high-energy fast  
chargers.

è Charging time: several minutes

è Power involved: >200 kW

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How does it work?

Introduction to eBus Depots

There are three main use cases recommended for the electrical installation, depending on the customer's needs:

Use case 1:

“Keep it simple, grid supply”

Build and enable the electrical infrastructure to supply energy to the eBuses.

Use case 2:

“Self-consume, grid tied”

Build and enable the electrical infrastructure while integrating the renewable energy sources.

Manage energy sources for the eBuses, intended to optimize both technical and economic parameters.

Use case 3:

“Run off grid”

Build electrical infrastructure with the ability to disconnect from the grid to help:

- Increase availability (lack of supply from the grid)
- Optimize energy supply prices
- Enhance stability across the internal network (“microgrid”) once disconnected from external energy sources.

Public eBus Depot Use Cases

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EcoStruxure Power Value Proposition

Apps,  
analytics,  
and  
services

Edge

Control

Connected  
products

Fleet Management

(Third party)

for eBus Depots

EV

charger

Circuit

breaker

Cloud-Based Advisor Services for Asset  
Management, EV Charging and distributed energy  
resources (renewables)

Uninterruptible  
power supply

Power

meter

Power quality  
solutions

Panel

server

## 2. Operational Management

- Real-time monitoring and control of power system status and identification of abnormal temperature, insulation faults or power disturbances
  - EV Charging Expert to optimize the use of energy between every charging point
- Microgrid Automation to manage Distributed Energy Resources (DERs) and improve real-time grid stability and reliability

## 3. Analysis & Optimization

- Cloud-based predictive power asset maintenance with expert recommendation provided by our Schneider Electric service experts
- Consulting services including network audits, microgrid sizing services, power systems engineering and

sustainable energy procurement

- Microgrid optimization using a cloud-based platform with necessary algorithms to get the most out of the local energy resources
- EV advisor for advanced management of the charging process, connected to a route-planning application (third-party)

1. Primary Equipment

- MV/LV range of power Connected Products for protection, power correction and monitoring
- Battery Energy Storage Systems (BESSs) to improve grid flexibility and stability
- High powered DC electric vehicle charging units

AVEVA

System Platform

EcoStruxure

Power Operation /

Power Monitoring

Expert

EcoStruxure

EV Charging

Expert

Simulation Engine

EcoStruxure

Microgrid

Operation

Our solution to control and supply energy to eBus depots

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 SECTION 5 – Customer Stories  
 Specific pillars for eBus depots  
 EcoStruxure Power Value Proposition  
 EcoStruxure Power provides applications to support the challenges of eBus depots for  
 Railway  
 and Urban Transportation, with the following pillars:  
 Reliable  
 Electrification  
 Electrical Distribution  
 Monitoring and Alarming  
 Capacity Management  
 Power Event Analysis  
 Power Quality Monitoring,  
 Correction, and Compliance  
 Power Source and Load Control  
 Safety and Comfort  
 Enhance safety and comfort in  
 passenger stations and tunnels  
 Continuous Thermal Monitoring  
 Guided Procedures Through  
 Extended Reality  
 Digitalization  
 Operate centrally and  
 maintain infrastructure efficiently  
 Backup Power Testing  
 Circuit Breaker Settings Monitoring  
 Asset Performance  
 Decarbonization  
 Reduce energy consumption  
 and carbon footprint  
 Basic Energy Awareness  
 Advanced Energy Performance  
 Effective Energy Accounting  
 Energy and Environmental  
 Compliance  
 Electrification (eBus Depot)

Advanced Microgrid	
Improve reliability of	
electrical infrastructure	
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Our Digital Solutions and Services: Applications Overview	
■■■ Essential ■■ Recommended ■ Desirable Click on the blue links to have more	
information	
Capacity	
Management	
è Visualize real-time or historical power system capacity	
è Monitor and trend circuit or equipment loading	
è Provide information for capacity planning	
Reliable Electrification	
Power Event	
Analysis	
è Provide a user-friendly graphical tool to simplify and save time in event analysis	
è Provide an aggregated view of events in the same dashboard	
è Enable root cause analysis	
Reliable Electrification	

Power Quality  
Monitoring, Correction,  
and Compliance

è Power Quality Monitoring and Compliance: Monitor persistent steady state and event-based disturbances to better understand and analyze power quality disturbances

è Power Quality Correction: Correct over/under voltages, harmonics, etc.

Reliable Electrification

Power Source  
and Load Control

è Help isolate faults with relay automation and circuit breaker coordination

è Help preserve critical loads by automatically transferring to alternate power

è Help restore power quickly

è Get real-time visibility, automation and control of the entire electrical infrastructure

Reliable Electrification



è Provide real-time status of the electrical distribution system

è Help identify anomalies and notify the right personnel

è Aggregate onboard alarm data in an easy-to-understand way

è Take advantage of native integration of intelligent electrical devices

Reliable Electrification

Electrical Distribution

Monitoring and  
Alarming



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Continuous Thermal Monitoring	
è Monitor the temperature of busbar, cable, transformer, and withdrawable circuit breaker connections	
è Help detect poor connections at an early stage	
è Provide temperature alarming and reporting for fast response	
Guided Procedures Through XR	
è Use Extended Reality to perform step-by-step guidance	
è Benefit from “X-ray” vision and virtually overlaid contextual asset and site information, live data, events and alarms	
è Take advantage of remote collaboration	
Safety and Comfort	
Safety and Comfort	
Backup Power Testing	
è Automatically record key backup power test parameters such as run time, engine loading, exhaust and engine temperatures	
è Perform automated backup power test reporting	
Digitalization	
Circuit Breaker Settings Monitoring	
è Compare current circuit breaker settings with commissioned settings	
è Help detect inappropriate setting modifications periodically	
è Provide information for capacity planning	
Digitalization	
Asset Performance	
è Make asset health visible across the entire system	
è Streamline inspections using continuous asset health monitoring	
è Optimize maintenance planning with analytics and expert advice	
Digitalization	



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Effective Energy

Accounting

Identify areas for possible energy conservation measures:

è Utility Bill Verification: Identify billing errors by comparison with a shadow bill

è Cost Allocation: Allocate energy costs to terminals or departments for accurate billing

è Power Factor correction: Mitigate harmonic effects and power quality issues

Decarbonization

Basic Energy

Awareness

è Energy Monitoring: Increase awareness of energy usage by creating easy-to-  
understand graphical dashboards and reports from data

è Cost Allocation: Identify "quick-win" opportunities for energy savings	
Decarbonization	
è Energy Efficiency Compliance: Report effectively about local/global energy and environmental building code compliance	
è Greenhouse Gas Reporting: Track and report emissions effectively to help cut carbon emissions	
Decarbonization	
Energy and Environmental Compliance	
■ ■	
■	
■	
Advanced Microgrid	
è Enhance power system reliability, despite grid instability often resulting from powerful storms and grid unavailability	
è Reduce carbon emissions and optimize cost efficiency by leveraging Distributed Energy Resources (DERs)	
Decarbonization	
■ ■	
Advanced Energy Performance	
è Energy Performance: Normalize energy data (e.g. with respect to building area) to give context. Analyze energy performance in context using KPIs	
è Energy Benchmarking: Compare energy usage with respect to other comparable facilities	
è Energy Modeling and Verification: Model the energy usage versus energy drivers	
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è	Power the bus depot with an end-to-end electrical distribution solution for charging your electrical buses	
è	Integrate and manage local power generation and batteries for self-consumption of renewable energy or for resiliency purposes	
	Decarbonization	
	Electrification	
	(EV Charging for eBus Depot)	
	■■■	
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#### Reference Electrical and Digital Architectures

Typical electrical architecture Reference digital architecture

Find the Schneider Electric products necessary  
to implement the selected applications.

Then find their location in the electrical  
architecture.

Find how the products, software  
solutions and cloud services are  
connected in the digital architecture.

Public Typical Electrical Architecture for e-Bus Depots

Public Reference Digital Architecture for e-Bus Depots

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The objective of this section is to:

- Introduce tunnel systems
  - Review EcoStruxure Power value propositions and the associated applications for tunnel systems
  - Provide reference electrical and digital architectures
- EcoStruxure Power  
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What is it?

Introduction to Tunnel Systems

Railway tunnels allow crossing of geographical landforms while respecting the layout  
limitations of the railway lines.

They involve major civil engineering works and the supply of systems to improve the safe  
use of the infrastructure.

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Access Control/Ventilation

How does it work?

Introduction to Tunnel Systems

A typical tunnel system consists of multiple technical systems that work in coordination in order to fulfill the operational plan. These include:

Telecom Fire Detection Power Supply

Drainage Lighting Weather

Forecasting

Signaling

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Main components of the electrical architecture	
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EcoStruxure Power Value Proposition

Apps,  
analytics,  
and services

Edge  
Control  
Connected  
products

for Tunnel Systems

Cloud-Based Advisor Services for asset management, data integrity,  
and workforce empowerment with extended reality guidance

AVEVA

System Platform

Protection  
relay

Remote  
terminal unit

Circuit  
breaker

Safety  
control unit

RIO  
drop

Control  
unit

Power  
quality meter

Protection  
device

UPS Power quality  
solutions

Automatic  
transfer switch

Variable  
speed drive

Energy  
meter

Panel  
server

2. Operational Management

Edge Control for all systems such as elevators, escalators,  
lighting, HVAC, drainage, ventilation, etc.

These systems can be:

- Option 1: centrally controlled (from the Control Center) using Supervisory Control and Data Acquisition (SCADA)
- Option 2: locally controlled using onsite HMIs or mobile apps

A software interface is used to exchange the control perimeter between the local tunnel system and the Control Center.

### 3. Analysis & Optimization

- Cloud-based predictive power asset maintenance with expert recommendation provided by our Schneider Electric service experts
- Consulting Services including network and power quality audits
- Augmented reality guidance for complicated or rarely performed procedures AVEVA System Platform EcoStruxure Power Operation / Power Monitoring Expert Cooling Local HMI

Our solution to control and supply energy to tunnel systems

### 1. Primary Equipment

Connected products include protective and electrical network automation devices, power meters, power conditioning units (UPS and power quality solution), and building automation.

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Specific pillars for tunnel systems  
EcoStruxure Power Value Proposition  
EcoStruxure Power provides applications to support the challenges of tunnel systems for  
Railway  
and Urban Transportation, with the following pillars:  
Reliable  
Electrification  
Electrical Distribution  
Monitoring and Alarming  
Capacity Management  
Power Event Analysis  
Power Quality Monitoring,  
Correction, and Compliance  
Power Source and Load Control  
Safety and Comfort  
Enhance safety and comfort in  
passenger stations and tunnels  
Continuous Thermal Monitoring  
Guided Procedures Through  
Extended Reality  
Digitalization  
Operate centrally and  
maintain infrastructure efficiently  
Backup Power Testing  
Circuit Breaker Settings Monitoring  
Asset Performance  
Decarbonization  
Reduce energy consumption  
and carbon footprint  
Basic Energy Awareness  
Advanced Energy Performance  
Energy and Environmental  
Compliance  
Effective Energy Accounting

Improve reliability of  
electrical infrastructure  
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Our Digital Solutions and Services: Applications Overview

■■■ Essential ■■ Recommended ■ Desirable Click on the blue links to have more  
information

Capacity

Management

è Visualize real-time or historical power system capacity

è Monitor and trend circuit or equipment loading

è Provide information for capacity planning

Reliable Electrification

Power Event

Analysis

è Provide a user-friendly graphical tool to simplify and save time in event analysis

è Provide an aggregated view of events in the same dashboard

è Enable root cause analysis

Reliable Electrification

Power Quality

Monitoring, Correction,  
and Compliance

è Power Quality Monitoring and Compliance: Monitor persistent steady state and event-based disturbances to better understand and analyze power quality disturbances

è Power Quality Correction: Correct over/under voltages, harmonics, etc.

Reliable Electrification

Power Source  
and Load Control

è Help isolate faults with relay automation and circuit breaker coordination

è Help preserve critical loads by automatically transferring to alternate power

è Help restore power quickly

è Get real-time visibility, automation and control of the entire electrical infrastructure

Reliable Electrification

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è Provide real-time status of the electrical distribution system

è Help identify anomalies and notify the right personnel

è Aggregate onboard alarm data in an easy-to-understand way

è Take advantage of native integration of intelligent electrical devices

Reliable Electrification

Electrical Distribution

Monitoring and  
Alarming

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information

Continuous Thermal  
Monitoring

è Monitor the temperature of busbar, cable, transformer, and withdrawable circuit breaker  
connections

è Help detect poor connections at an early stage

è Provide temperature alarming and reporting for fast response

Guided Procedures  
Through XR

è Use Extended Reality to perform step-by-step guidance

è Benefit from “X-ray” vision and virtually overlaid contextual asset and site information,  
live data, events and alarms

è Take advantage of remote collaboration

Safety and Comfort

Safety and Comfort

Backup Power

Testing

è Automatically record key backup power test parameters such as run time, engine  
loading, exhaust and engine temperatures

è Perform automated backup power test reporting

Digitalization

Circuit Breaker

Settings Monitoring

è Compare current circuit breaker settings with commissioned settings

è Help detect inappropriate setting modifications periodically

è Provide information for capacity planning

Digitalization

Asset Performance

è Make asset health visible across the entire system

è Streamline inspections using continuous asset health monitoring

è Optimize maintenance planning with analytics and expert advice

Digitalization

■■■

■■■



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Our Digital Solutions and Services: Applications Overview

■■■ Essential ■■ Recommended ■ Desirable Click on the blue links to have more  
information

Effective Energy  
Accounting

Identify areas for possible energy conservation measures:

- è Utility Bill Verification: Identify billing errors by comparison with a shadow bill
- è Cost Allocation: Allocate energy costs to terminals or departments for accurate billing
- è Power Factor correction: Mitigate harmonic effects and power quality issues

Decarbonization  
Basic Energy  
Awareness

- è Energy Monitoring: Increase awareness of energy usage by creating easy-to-understand graphical dashboards and reports from data
- è Cost Allocation: Identify "quick-win" opportunities for energy savings

Decarbonization  
è Energy Efficiency Compliance: Report effectively about local/global energy and environmental building code compliance  
è Greenhouse Gas Reporting: Track and report emissions effectively to help cut carbon emissions

Decarbonization  
Energy and  
Environmental  
Compliance

■ ■ ■

■ ■

■ ■

Advanced Energy  
Performance

è Energy Performance: Normalize energy data (e.g. with respect to building area) to give context. Analyze energy performance in context using KPIs  
è Energy Benchmarking: Compare energy usage with respect to other comparable facilities  
è Energy Modeling and Verification: Model the energy usage versus energy drivers  
Decarbonization

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Reference Electrical and Digital Architectures  
Typical electrical architecture Typical digital architecture  
Find the Schneider Electric products necessary  
to implement the selected applications.  
Then find their location in the electrical  
architecture.  
Find how the products, software  
solutions and cloud services are  
connected in the digital architecture.  
Public Typical Electrical Architecture for Tunnel Systems  
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The objective of this section is to:

- Introduce depots and workshops
- Review EcoStruxure Power value

propositions and the associated  
applications for depots and  
workshops

- Provide reference electrical  
and digital architectures

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What is it?

Introduction to Depots and Workshops

A depot or workshop is a railway facility where preventive and corrective maintenance tasks are carried out on rolling stock. The difference between the two is not totally clear, but

the former is usually more focused on train storage and their periodic maintenance, while the latter is more focused on major repairs. However, it is common for both types of services to be carried out within the same building.

Main line Stabling Area

Yard Area  
Pway &  
Infrastructure  
Building  
Workshop  
Building  
Car  
Delivery  
Test  
Track  
Depot  
Control  
Center  
Administrative  
Building  
1  
4  
5

A train depot/workshop has the following main areas:

1. Train yard
2. Train workshop building
3. Train wash plant
4. Test track
5. Depot control center

Wash  
Plant  
Wheel  
Lathe Store  
2 3

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Drainage	
Traction	
Power	
How does it work?	
Introduction to Depots and Workshops	
Typical depots and workshops consist of multiple technical systems that work in coordination in order to fulfill the operational plan. These include:	
Power Supply Microgrid	
Management	
Lighting Washing	
Maintenance	
Safety Process	
HVAC*Fire Detection	
* Heating, Ventilation, Air Conditioning	
Access Control	
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Main components of the electrical architecture

Introduction

Public Main Components of the Electrical Architecture for Depots and Workshops

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Our solution to control and supply energy to depots and workshops

EcoStruxure Power Value Proposition

Apps,

analytics,

and services

Edge  
Control  
Connected  
products  
for Depots and Workshops  
Cloud-Based Advisor Services for asset management, data integrity,  
and workforce empowerment with extended reality guidance

AVEVA  
System Platform  
Protection  
relay  
Remote  
terminal unit  
Circuit  
breaker  
Safety  
control unit  
Control  
unit  
Power  
quality meter  
Protection  
device  
UPS Power quality  
solutions  
Automatic  
transfer switch  
Variable  
speed drive  
Energy  
meter  
Panel  
server

## 2. Operational Management

Edge Control for all systems such as depot power, traction  
power, lighting, HVAC, drainage, etc.

These systems can be:

- Option 1: centrally controlled (from the Control Center)  
using Supervisory Control and Data Acquisition (SCADA)
- Option 2: locally controlled using onsite HMIs or mobile  
apps

A software interface is used to exchange the control  
perimeter between the depot and the Control Center.

## 3. Analysis & Optimization

- Cloud-based predictive power asset maintenance with expert recommendation provided by our Schneider Electric service experts
- Consulting Services including network and power quality audits
- Augmented reality guidance for complicated or rarely performed procedures AVEVA System Platform EcoStruxure Power Operation / Power Monitoring Expert Cooling Local HMI EcoStruxure Microgrid Operation Control Unit Drive controller

#### 1. Primary Equipment

Connected products include protective and electrical network automation devices, power meters, power conditioning units (UPS and power quality solution), and building automation.

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#### Depots and Workshops

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 Specific pillars for depots and workshops  
 EcoStruxure Power Value Proposition  
 EcoStruxure Power provides applications to support the challenges of depots and  
 workshops for Railway  
 and Urban Transportation, with the following pillars:  
 Reliable  
 Electrification Safety and Comfort  
 Enhance safety and comfort in  
 passenger stations and tunnels  
 Digitalization  
 Operate centrally and  
 maintain infrastructure efficiently  
 Decarbonization  
 Reduce energy consumption  
 and carbon footprint  
 Capacity Management Guided Procedures Through  
 Extended Reality Circuit Breaker Settings Monitoring Basic Energy Awareness  
 Power Event Analysis Asset Performance Advanced Energy Performance  
 Power Quality Monitoring,  
 Correction, and Compliance Advanced Microgrid  
 Electrical Distribution  
 Monitoring and Alarming Continuous Thermal Monitoring Backup Power Testing Effective  
 Energy Accounting  
 Improve reliability of  
 electrical infrastructure  
 Overhead Line Protection and  
 Automation  
 Power Source and Load Control Energy and Environmental  
 Compliance  
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Our Digital Solutions and Services: Applications Overview

■■■ Essential ■■ Recommended ■ Desirable Click on the blue links to have more  
information

Capacity

Management

è Visualize real-time or historical power system capacity

è Monitor and trend circuit or equipment loading

è Provide information for capacity planning

Reliable Electrification

Power Event

Analysis

è Provide a user-friendly graphical tool to simplify and save time in event analysis

è Provide an aggregated view of events in the same dashboard

è Enable root cause analysis

Reliable Electrification

Power Quality

Monitoring, Correction,  
and Compliance

è Power Quality Monitoring and Compliance: Monitor persistent steady state and event-  
based disturbances to better understand and analyze power quality disturbances

è Power Quality Correction: Correct over/under voltages, harmonics, etc.

Reliable Electrification

Power Source

and Load Control

è Help isolate faults with relay automation and circuit breaker coordination

è Help preserve critical loads by automatically transferring to alternate power

è Help restore power quickly  
è Get real-time visibility, automation and control of the entire electrical infrastructure  
Reliable Electrification

■ ■

■ ■ ■

■ ■ ■

■ ■ ■

è Provide real-time status of the electrical distribution system  
è Help identify anomalies and notify the right personnel  
è Aggregate onboard alarm data in an easy-to-understand way  
è Take advantage of native integration of intelligent electrical devices

Reliable Electrification

Electrical Distribution

Monitoring and

Alarming

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information	
Continuous Thermal Monitoring	
è Monitor the temperature of busbar, cable, transformer, and withdrawable circuit breaker connections	
è Help detect poor connections at an early stage	
è Provide temperature alarming and reporting for fast response	
Guided Procedures Through XR	
è Use Extended Reality to perform step-by-step guidance	
è Benefit from “X-ray” vision and virtually overlaid contextual asset and site information, live data, events and alarms	
è Take advantage of remote collaboration	
Safety and Comfort	
Safety and Comfort	
Backup Power Testing	
è Automatically record key backup power test parameters such as run time, engine loading, exhaust and engine temperatures	
è Perform automated backup power test reporting	
Digitalization Circuit Breaker Settings Monitoring	
è Compare current circuit breaker settings with commissioned settings	
è Help detect inappropriate setting modifications periodically	
è Provide information for capacity planning	
Digitalization	■ ■ ■
	■ ■
	■ ■
	■
è Provide distributed control and supervision of overhead (catenary) line disconnectors	
Reliable Electrification Overhead Line Protection and Automation	■ ■ ■
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- Essential ■■ Recommended ■ Desirable Click on the blue links to have more information
- Effective Energy Accounting

Identify areas for possible energy conservation measures:

- è Utility Bill Verification: Identify billing errors by comparison with a shadow bill
- è Cost Allocation: Allocate energy costs to terminals or departments for accurate billing
- è Power Factor correction: Mitigate harmonic effects and power quality issues

Decarbonization

Basic Energy

Awareness

- è Energy Monitoring: Increase awareness of energy usage by creating easy-to-understand graphical dashboards and reports from data

- è Cost Allocation: Identify "quick-win" opportunities for energy savings

Decarbonization

■■■

■■

Advanced

Microgrid

- è Enhance power system reliability, despite grid instability often resulting from powerful storms and grid unavailability

- è Reduce carbon emissions and optimize cost efficiency by leveraging Distributed Energy Resources (DERs)

Decarbonization



Asset Performance

- è Make asset health visible across the entire system
- è Streamline inspections using continuous asset health monitoring
- è Optimize maintenance planning with analytics and expert advice

Digitalization



Advanced Energy  
Performance

- è Energy Performance: Normalize energy data (e.g. with respect to building area) to give context. Analyze energy performance in context using KPIs
- è Energy Benchmarking: Compare energy usage with respect to other comparable facilities
- è Energy Modeling and Verification: Model the energy usage versus energy drivers

Decarbonization



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information

è Energy Efficiency Compliance: Report effectively about local/global energy and environmental building code compliance

è Greenhouse Gas Reporting: Track and report emissions effectively to help cut carbon emissions

Decarbonization

Energy and Environmental Compliance

■ ■

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Reference Electrical and Digital Architectures

Typical electrical architecture Typical digital architecture

Find the Schneider Electric products necessary to implement the selected applications.

Then find their location in the electrical architecture.

Find how the products, software solutions and cloud services are

connected in the digital architecture.

Public Typical Electrical Architecture for for Depots and Workshops

Public Typical Digital Architecture for Depots and Workshops

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WHY READ

THIS SECTION?

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The objective of this section is to:

- Introduce the control center
- Review EcoStruxure Power value propositions and the associated applications for the control center
- Provide reference architectures

EcoStruxure Power

Digital Solutions and Services

for:

à Control Center

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What is it?

Introduction to the Control Center

The Control Center is a central location from which the following facilities (described in the  
previous sections)

are operated:

- Traction Substations
- Overhead Lines
- Auxiliary Power System
- Passenger Stations
- Tunnel Systems
- Datacenters

Its purpose is to achieve compliance with the operational plan,  
with the minimum necessary resources.

Comment:

- Initially, the responsibility was  
located at the local levels of the  
facilities.
- Now, process automation makes it  
possible to delegate responsibility to  
a higher hierarchy facility and

increase the operational efficiency.

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Real-time Operation Asset Management

Objective

Add advanced facility maintenance  
strategies to traditional corrective  
and preventive maintenance.

This helps optimize asset availability  
without increasing maintenance costs.

Objective

Optimize operations with the analytics  
applied to data acquired from the field  
devices. This helps to empower the  
workforce.

Operational Efficiency

How does it work? (1/2)

Introduction to the Control Center

The control center is the facility that centrally manages the railway installations. The most

relevant element of this facility is the control room, from which the system operators are mandated to perform the following functions:

How

- Monitor and control the facilities including the implementation of automated systems that facilitate any changes in the configuration of the tasks.
- Manage operations for all the facilities (full delegation, exceptions for abnormal situations).
- Manage emergency scenarios for passenger stations and tunnel systems.

Objective

Manage the operational plan of the facilities remotely and centrally. This helps to optimize the state of operation under various situations.

How

Collect data from field devices to monitor asset health and perform:

- Condition-based maintenance: Proactive monitoring depending on the condition of the asset. Maintenance is triggered when critical parameters vary beyond their “normal” range.
- Predictive maintenance: a maintenance task is performed when measured variables of an asset deviate from those indicated as normal by a digital model of the asset.

How

Use data collected at operational level to implement advanced functionalities such as:

- Electrical simulation: commonly used for operator training or operation support, and during the facility electrical design phase.

- Basic and advanced reporting:  
advanced representation of  
information and generation of new  
data, using data processing  
techniques and AI models.

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A Redundancy-based Strategy

The Control Center is responsible for the  
operations of all the facilities (except in  
abnormal situations mainly related to  
maintenance and telecom network issues).

Therefore, it has a huge responsibility,  
and its availability is critical.

To improve availability of the control center,  
essential services are usually implemented  
with redundancy:

- Redundancy of the components inside the  
control center

- Redundancy of the control center in other locations (emergency control center).

How does it work? (2/2)

Introduction to the Control Center

In case of failure of a component or of unavailability of the control center, the redundant component / control center

takes over the function/service until repair/availability.

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Apps,  
analytics,  
and services

Edge

Control

Connected

products

for Control Centers

Cloud-Based Advisor Services for asset management, data integrity and

workforce empowerment with extended reality guidance

AVEVA

Insight

EcoStruxure

XR Operator

Advisor

EcoStruxure

EV

Advisor

EcoStruxure

Microgrid

Advisor

EcoStruxure

Building

Advisor

AVEVA

System Platform

EcoStruxure

Power Operation /

Power Monitoring

Expert

EcoStruxure

Building Operation

Simulation Engine

EcoCare

Membership \*

EcoStruxure

Cybersecurity

Admin Expert

## 2. Operational Management

Among the usual tasks to be carried out by the operators of the control center, we can highlight the following:

- Assurance of power supply to trains and rail consumers
- Mitigation of the impact of electrical faults in the railway traction scope.
- Implementation of the different operational / emergency scenarios defined for passenger stations and tunnels.
  - Central management of the cybersecurity for the full architecture.

## 3. Analysis & Optimization

Applications for advanced asset management, analysis and optimization of operations:

- Predictive and condition-based maintenance for electrical assets

- Integration, contextualization, analysis, and representation of information
- Advanced management of microgrids and electric chargers, including technical and economic aspects.
- Consulting Services, including network and power quality audits
- Augmented reality guidance for complicated or rarely performed procedures
- 1. Primary Equipment

Data provided by connected products from the different facilities

Energy control of traction, non-traction and catenary systems

Passenger Stations Tunnels

Our solution to control and supply energy to control centers

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Specific pillars for control centers

## EcoStruxure Power Value Proposition

EcoStruxure Power provides applications to support the challenges of control centers for  
Railway

and Urban Transportation, with the following pillars:

Reliable

Electrification

Improve reliability of  
electrical infrastructure

Electrical Distribution

Monitoring and Alarming

Capacity Management

Power Event Analysis

Power Quality Monitoring,  
Correction, and Compliance

Overhead Line Protection  
and Automation

Safety and Comfort

Enhance safety and comfort in  
passenger stations and tunnels

Continuous Thermal Monitoring

Guided Procedures Through

Extended Reality

Digitalization

Operate centrally and  
maintain infrastructure efficiently

Circuit Breaker Settings

Monitoring

Asset Performance

Operator Training Simulation

Simulate Before Operate

Cybersecurity Central

Management

Asset Preventive Maintenance

Asset analytics

Massive Data Archive  
and Contextualization

Rail Power Design

Decarbonization

Reduce energy consumption  
and carbon footprint

Basic Energy Awareness

Advanced Energy Performance

Energy and Environmental

Compliance

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Our Digital Solutions and Services: Applications Overview	
■■■ Essential ■■ Recommended ■ Desirable Click on the blue links to have more information	
Capacity Management	
è Visualize real-time or historical power system capacity	
è Monitor and trend circuit or equipment loading	
è Provide information for capacity planning	
Reliable Electrification	
Power Event Analysis	
è Provide a user-friendly graphical tool to simplify and save time in event analysis	

è Provide an aggregated view of events in the same dashboard

è Enable root cause analysis

Reliable Electrification

Power Quality

Monitoring, Correction,

and Compliance

è Power Quality Monitoring and Compliance: Monitor persistent steady state and event-based disturbances to better understand and analyze power quality disturbances

è Power Quality Correction: Correct over/under voltages, harmonics, etc.

Reliable Electrification

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è Provide real-time status of the electrical distribution system

è Help identify anomalies and notify the right personnel

è Aggregate onboard alarm data in an easy-to-understand way

è Take advantage of native integration of intelligent electrical devices

Reliable Electrification

Electrical Distribution

Monitoring and

Alarming

■ ■ ■

è Provide distributed control and supervision of overhead (catenary)

line disconnectors

Reliable Electrification

Overhead Line

Protection

and Automation

■ ■ ■

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Continuous Thermal	
Monitoring	
è Monitor the temperature of busbar, cable, transformer, and withdrawable circuit breaker	connections
è Help detect poor connections at an early stage	
è Provide temperature alarming and reporting for fast response	
Guided Procedures	
Through XR	
è Use Extended Reality to perform step-by-step guidance	
è Benefit from “X-ray” vision and virtually overlaid contextual asset and site information,	live data, events and alarms
è Take advantage of remote collaboration	
Safety and Comfort	
Safety and Comfort	
Circuit Breaker	
Settings Monitoring	
è Compare current circuit breaker settings with commissioned settings	
è Help detect inappropriate setting modifications periodically	
è Provide information for capacity planning	
Digitalization	
Asset Performance	
è Make asset health visible across the entire system	
è Streamline inspections using continuous asset health monitoring	
è Optimize maintenance planning with analytics and expert advice	
Digitalization	
■■■	
■	
■	
■■	

Operator Training  
Simulation

- è Train new employees and build confidence on new systems
  - è Practice operation within a simulated but highly realistic environment to enhance safety and operational efficiency
  - è Track and review trainee actions to analyze and challenge them
- Digitalization



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■■■ Essential ■■ Recommended ■ Desirable Click on the blue links to have more information

Simulate Before  
Operate

- è Provide operators with a list of potential side effects, prior to executing a command
- è Empower employees to feel more confident when operating their facilities by providing real-time guidance
- è Reduce human error that could lead to outages or safety concerns

Digitalization Cybersecurity Central Management è Integrate cybersecurity solutions allowing the operations team to have visibility of key cybersecurity data è Help manage/maintain cybersecurity control points è Align to cybersecurity standards and best practices to strengthen OT security Digitalization Asset Preventive Maintenance è Minimize inventory costs and improve spare part availability è Manage mobile work for more accurate and timely data collection è Receive proactive maintenance information by identifying labor/material/tools/drawings on work order Digitalization Asset Analytics è Analyze utilization, efficiency, and condition-management of assets. Receive alerts and notifications è Provide automated analytics using supervised or unsupervised machine learning è Create dynamic data visualizations and asset frameworks for contextual data viewing Digitalization Massive Data Archive and Contextualization è Collect and store in one single place real-time data from operating assets with sub-second granularity è Contextualize and visualize data Digitalization ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ Reference Guide EcoStruxure Power for Railway and Urban Transportation Public SECTION 3 – Digital Solutions and Services across the Facilities SECTION 2 – How EcoStruxure Power Can Support the Railway Industry 2- Traction Substations 3- Auxiliary Powers Systems 5- eBus Depots 6- Tunnel Systems	
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Our Digital Solutions and Services: Applications Overview	
■■■ Essential ■■ Recommended ■ Desirable	Click on the blue links to have more information
Rail Power Design	
è Visualize and analyze traction power systems using synchronized geospatial and schematic views	
è Simulate and analyze operation of combined DC and AC power supply networks	
è Model traction power-specific devices with built-in components and engineering libraries	
Digitalization	
Effective Energy	
Accounting	
Identify areas for possible energy conservation measures:	
è Utility Bill Verification: Identify billing errors by comparison with a shadow bill	
è Cost Allocation: Allocate energy costs to terminals or departments for accurate billing	
è Power Factor correction: Mitigate harmonic effects and power quality issues	
Decarbonization	
Basic Energy	
Awareness	
è Energy Monitoring: Increase awareness of energy usage by creating easy-to-understand graphical dashboards and reports from data	
è Cost Allocation: Identify "quick-win" opportunities for energy savings	
Decarbonization	
Advanced	
Microgrid	
è Enhance power system reliability, despite grid instability often resulting from powerful storms and grid unavailability	
è Reduce carbon emissions and optimize cost efficiency by leveraging Distributed Energy Resources (DERs)	
Decarbonization	

■■■

■■

■■

■■

## Advanced Energy Performance

è Energy Performance: Normalize energy data (e.g. with respect to building area) to give context. Analyze energy performance in context using KPIs

è Energy Benchmarking: Compare energy usage with respect to other comparable facilities

è Energy Modeling and Verification: Model the energy usage versus energy drivers

## Decarbonization

■■

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#### Our Digital Solutions and Services: Applications Overview

■■■ Essential ■■ Recommended ■ Desirable Click on the blue links to have more  
information

è Energy Efficiency Compliance: Report effectively about local/global energy and  
environmental building code compliance

è Greenhouse Gas Reporting: Track and report emissions effectively to help cut carbon emissions

Decarbonization

Energy and

Environmental

Compliance

è Power the bus depot with an end-to-end electrical distribution solution for charging your electrical buses

è Integrate and manage local power generation and batteries for self-consumption of renewable energy or for resiliency purposes

Decarbonization

Building

Automation

è Monitor and control the electromechanical systems present in the passenger station

è Automate processes within the passenger station

è Implement operational and emergency scenarios

Decarbonization

Electrification

(EV Charging

for eBus Depot)

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Reference Electrical and Digital Architectures  
Typical reference architecture Typical digital architecture  
Find the Schneider Electric digital solutions and  
services relevant to implement the selected  
applications.  
Then find their location in the reference  
architecture.  
Find how the products, software  
solutions and cloud services are  
connected in the digital architecture.  
Public Typical Reference Architecture for the Control Center  
Public Reference Digital Architecture for the Control Center  
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WHY READ  
THIS SECTION?  
Design Considerations  
à Control Center Solutions

à Communication Protocols  
 à Time Synchronization  
 à Integration with BMS  
 à Cybersecurity  
 à Environmental Data Program  
 The objective of this section is to:  
 • Provide the details of the critical  
 system design components to be  
 considered while designing digital  
 architecture  
 • Addresses design considerations  
 of the electrical installation in the  
 context of communications, data,  
 time and cybersecurity  
 à Control Strategies for Passenger Stations  
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The control center centralizes the operation of railway facilities.

Schneider Electric offers the following solutions for effective management and control:

How to Choose a Solution for Operation Control Centers

Management

of Energy

Management

of Passenger Stations

Control of Railway  
Tunnels  
Control of  
Datacenters  
AVEVA  
System Platform  
EcoStruxure  
Power Monitoring  
Expert  
EcoStruxure  
Building Operation  
EcoStruxure  
IT Expert  
AVEVA  
System Platform  
AVEVA  
System Platform  
Basic functionalities  
EcoStruxure  
Power Operation  
Complex systems  
Building approach  
Industrial approach  
Additional analysis  
EcoStruxure  
Power Monitoring  
Expert  
• Continuous thermal  
monitoring  
• Power event  
analysis  
• Power quality  
monitoring  
• Energy usage  
analysis  
• Energy efficiency  
& power quality  
compliance  
• Good capabilities  
for integration with  
external systems  
• Industrial  
interoperability  
protocols

- Management of power supply
- Monitoring of environmental conditions
  - Railways
- Building element integration
  - Building management
- Interoperability protocols
  - Urban Transportation
- Higher integration needs of external systems
  - Industrial interoperability protocols
  - Basic operation and monitoring
- Alarm management
  - Access control
  - Automatism and interlocks
  - Basic reporting
- Continuous thermal monitoring
- Power event analysis
  - Power quality monitoring
  - Energy usage analysis
  - Energy efficiency & power quality compliance
  - Advanced alarm management
- Advanced reporting & data analytics tools
- Emergency control center
  - Graphical event

replay  
 • Scalability  
 Additional analysis  
 EcoStruxure  
 Power Monitoring  
 Expert  
 • Continuous thermal  
 monitoring  
 • Power event analysis  
 • Power quality  
 monitoring  
 • Energy usage analysis  
 • Energy efficiency  
 & power quality  
 compliance  
 Tunnel Management  
 Additional analysis  
 EcoStruxure  
 Power Monitoring  
 Expert  
 • Continuous thermal  
 monitoring  
 • Power event  
 analysis  
 • Power quality  
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Control Strategies for Passenger Stations

Passenger stations can be conceptualized in various ways, depending on the approach to automation and the perception of the facility.

Surface-installed passenger station    Underground passenger station  
Application

- Mainlines or in high-speed rail systems

Control strategy

- Considered as a specialized type of building
- Alignment with building management system

Typical equipment

- Floor controllers (AS-P)
- Room controllers (RP-C)
- Building Operation & Building Advisor for centralizing station information.

Telecommunication Protocols

- KNX
- DALI
- Other standard telecontrol protocols.

Application

- Urban transportation

Control strategy

- Considered as an industrial facility
- Use of industrial automation for critical components like ventilation

Typical equipment

- PLCs based solutions (M580 and M340)
- AVEVA System Platform for centralizing information

Telecommunication Protocols

- OPC (for advanced data modeling and cybersecurity features).
- Modbus (for interconnexion with legacy systems)

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Alternating Current (AC) Direct Current (DC)

Application

Mainly in high performance systems such as mainlines or in high-speed rail systems

- Railway systems with very high energy demand
  - High-speed travel
- Railway systems with a very high frequency of train movements

Control Strategy

- Use elements borrowed from electrical distribution

Typical equipment

- Specialized controllers for managing electrical devices with a native implementation of most of the necessary functions for substation automation

Interoperability standard

- IEC 61850: describes the implementation of the functions present in a substation from both a constructive and functional perspective

Advantage

- Fully adapted to control an electrical process
  - Analysis of electrical events
  - Excellent performance
- Maintenance management & engineering tools
- Good interoperability due to the use of IEC 61850
  - Cybersecurity requirements

Drawback

- Higher price

#### Application

Mainly urban transportation

- Systems with lower energy demand (tramways)
- Networks with a strong tradition in this technology (metros)

#### Control Strategy

- Choose a general-purpose programmable logic controller (PLC) as the main element for their automation

#### Typical equipment

- Use general-purpose programmable logic controllers (PLCs) for automation

#### Interoperability standard

- Modbus (and variants)

#### Advantage

- Simple configuration
- Price competitive

#### Drawback

- Limitation in meeting usual standards of the electrical world
  - Limited performance
- Limitations due to Modbus: deficiencies in electrical object modeling, event dating, and cybersecurity. Can be addressed using non-standard versions of the protocol or OPC UA protocol (widely used in industrial environments).

Control strategy is different whether the system is supplied with alternating or direct current:

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Modern electrical distribution systems, especially in critical infrastructure like railways and urban transportation, use various industrial protocols for data communication from devices such as circuit breakers, relays, controllers, and sensors. Key protocols include:  
Commonly used for high-speed medium voltage automation.

Provides:

- Consistent measurement naming
  - Fast device-to-device communication (GOOSE messaging)
  - Communication to a SCADA system
- IEC 61850  
Modbus RTU and  
Modbus TCP/IP

Common in low voltage systems for metering, protection, and control.

Can convert serial Modbus to Modbus TCP/ IP for data integration with a power monitoring or SCADA software .

Wireless

( IEC 802.15-4, e.g. Zigbee)

Enables low-powered simple data communication for energy and condition monitoring sensors.

Can be aggregated and converted to Modbus TCP/IP for integration with a power monitoring or SCADA software

(using a data concentrator and protocol converter device)

EcoStruxure Power natively integrates with Schneider Electric devices to obtain real-time, historical event and data

logs, as well as waveforms. However, it is common for 3rd party devices to store event logs and waveform data in

proprietary formats. The EcoStruxure Power platform can acquire data from any device

using the open protocols mentioned above, provided the data is available in non-vendor-proprietary formats.

- Communications

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Time Synchronization

Why consider time synchronization of connected products?

To operate, EcoStruxure Power applications collect data from the connected products of the electrical installation (such as relays, trip units, power meter, sensors).

When applications analyze and correlate timestamped data from multiple connected products, it is crucial to make sure that their internal clocks are accurate relative to other devices and local time. The setting of devices to a single time reference is called time synchronization.

The choice of the time synchronization solution must be defined during the system design phase. It depends on the time criticality of the applications deployed to monitor and control the different parts of the installation.

Refer to next page for further explanations about time criticality.

- “How to Optimize Time-Synchronization and Data Recording for EcoStruxure Power Digital Applications” Technical Guide

For a detailed coverage of time synchronization, refer to:

- Data recording and Timestamping section in the EcoStruxure Power Design Guide  
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What is the time criticality of an application?

Time Synchronization

The time criticality of an application defines the level of time accuracy required for data timestamping to enable the proper operation of the application.

EcoStruxure Power categorizes applications into three levels of time criticality:

Example of time criticality:

- Continuous Thermal Monitoring: This application monitors the progressive rise in busbar connection temperature to help prevent fires. It has a low time criticality.
- Power Event Analysis: This application reconstructs the sequence of events among multiple electrical equipment to help understand the cause(s) of an incident. It has a high time criticality.

Refer to next page to learn how to select the appropriate time synchronization solution based on the time criticality.

- Time criticality of applications

Learn more about:

Digital Application Time Critical Time Accuracy Upper Limit Time Accuracy Lower Limit

High  $\pm 1$  ms  $\pm 10$  ms

Medium  $\pm 10$  ms  $\pm 1$  s

Low  $\pm 1$  s  $\pm 10$  s

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How to select the time synchronization solution based on time criticality?  
Time Synchronization

There are many options available for time synchronization protocols, which can make it challenging to develop a cohesive strategy for all connected devices. To achieve optimal performance while minimizing costs, it is common to enforce the most accurate protocols only in the sensitive areas of electrical distribution (e.g., the electrical supply of core industrial processes) and use less accurate solutions in areas with lower sensitivity (e.g., utilities).

The table below provides an overview of the solutions based on achieved time criticality and related costs:

To summarize the table :

- PTP provides the best performance versus cost option available today for highly time-critical applications, but is not available on all devices
- IRIG-B offers similar performance to PTP but comes with a much higher installation cost.
  - NTP is the next best alternative for medium time-criticality needs.
  - SNTP or Modbus are adequate for low time-critical applications.

Application Time Critical Typical Time Accuracy Protocol Media Protocol Typical Cost

High  $\pm 1$  ms Ethernet PTP (IEEE 1588) \$ \$

High  $\pm 1$  ms Serial IRIG-B \$ \$ \$

Medium  $\pm 10$  ms to 100 ms Ethernet NTP \$

Medium  $\pm 100$  ms Serial DCF77 \$ \$

Low  $\pm 1$  s Ethernet SNTP \$

Low  $\pm 1$  s Ethernet Over Modbus / ION from Edge Control \$

Low  $\pm 1$  s Serial 1 per 10 \$ \$

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Why integrate mechanical and electrical systems?

Integration with Building Automation Systems (BMS)

- Data Integration and Interoperability between Systems

Learn more about:

Need for data aggregation

Facility infrastructure is experiencing a convergence of information and operational systems. This is particularly true for Railway and Urban Transportation applications, where mechanical and electrical systems are essential infrastructure.

These systems are rapidly generating increasing amounts of data, with the addition of new sensors, meters, and other smart equipment. It is crucial to have robust software system with proper data aggregation from these devices.

Examples of mechanical and electrical systems integration in Railway

- Energy performance monitoring : Track and model facility energy usage;
- Asset management: View mechanical and electrical asset performance in one place;
- Fault management: Detect faults and respond through an integrated interface.

Benefits of systems integration

Integrating the systems:

- Creates a unified interface for visualizing, analyzing, and reporting data, simplifying daily tasks for operations and maintenance staff;
- Enables applications to utilize context from both systems to optimize the decision-making

processes;

- Enhances overall Operational efficiency

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Why plan the integration at the design phase?

Integration with Building Automation Systems (BMS)

- Data Integration and Interoperability between Systems

Learn more about:

Costly retrofit of existing installations

Traditionally, Power Management Systems

(electrical systems) and Building Management

Systems (including mechanical systems) are

designed in silos. The consequence is that it

leaves the end user with little to no electrical data

in operational systems.

Retrofitting this into an existing system can be quite costly. Therefore, it is essential to design the proper IoT electrical systems far in advance.

Advantages of early system integration

Enabling the BMS and PMS to integrate directly to relevant data allows the systems to perform as designed. Additionally, it also:

- Reduces cost and complexity by minimizing excessive wiring of electrical devices to mechanical control systems.

- Helps system integrators by enabling a seamless interface to manage facility operations and maintenance;

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How is data acquired and integrated within the architecture? (1/2)

Integration with Building Automation Systems (BMS)

Data acquisition

Digital electrical monitoring and control software acquires data from intelligent electrical devices via open communication protocols. This includes:

- Real-time information
- Historical power events
  - Data logs
- Electrical signal waveforms
  - Service diagnostics.

By default, BMS (Building Management Systems) cannot retrieve certain data from the electrical distribution, such as event logs, waveforms, and diagnostic data. Trying to do this directly with the BMS would require a tremendous amount of engineering. It is more efficient and native to let a PMS (Power Management System) collect the data from the electrical distribution and then integrate the PMS with the BMS.

- Data Integration and Interoperability between Systems

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How is data acquired and integrated within the architecture? (2/2)

Integration with Building Automation Systems (BMS)

Data Integration

The method/tool to integrate the data depends on the data type, and on the direction of the transfer:

The integration is performed through:

- An Extract Transform Load functions

Used for historical building management data to enable energy data correlation.

The integration is performed through:

- EcoStruxure Web Services

Used for real-time data, alarms, and historical data

- Web interface integration (Single Sign On)

Used for power and energy dashboards, graphical diagrams, trends, reports, and configuration pages

EcoStruxure Building Operation (EBO)

EcoStruxure Power Operation (EPO)

with Advanced Reporting and Dashboards

EcoStruxure Building Operation (EBO)

EcoStruxure Power Operation (EPO)

with Advanced Reporting and Dashboards

PublicExample of Combined Solution with EcoStruxure Building Operation and EcoStruxure Power Operation with Advanced Reporting and Dashboards

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ACCESS CONTROL  
Seven pillars to strengthen cybersecurity  
Cybersecurity

Protect electrical components by verifying the identity  
of any user requesting access to a component before  
activating the communication with that component.

When used in conjunction with security event  
logging, this will include ensuring ‘non-repudiation,’  
for example, a person cannot deny that they  
performed a particular action.

Access Control  
DATA CONFIDENTIALITY  
USE CONTROL  
DATA INTEGRITY  
DATA FLOW  
TIMELY RESPONSE TO EVENTS  
RESOURCE AVAILABILITY

Cybersecurity is no longer a question of competitive advantage or even minimizing damage.

It is a fundamental requirement for doing business today.  
Here are the seven essential pillars for improving it:

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Seven pillars to strengthen cybersecurity

Cybersecurity

Protect against unauthorized actions on component  
resources by verifying that the necessary privileges  
have been granted before allowing a user to perform  
the actions.

This must address what a hacker can potentially do if  
they access the system and counteract that by only  
giving the minimum level of access necessary for that  
user to perform their role.

Use Control

USE CONTROL

DATA CONFIDENTIALITY

DATA INTEGRITY

DATA FLOW  
TIMELY RESPONSE TO EVENTS  
RESOURCE AVAILABILITY  
ACCESS CONTROL

Cybersecurity is no longer a question of competitive advantage or even minimizing damage.  
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Cybersecurity  
Ensure that the components will perform as intended  
during operational and non-operational states, such  
as energy production and storage, or a maintenance  
shutdown.  
Consider a Circuit Breaker that is detecting potential  
issues in its operation: if the SCADA system is  
hacked and is forced to indicate everything is okay,

that could cause an unexpected and dangerous event.

Data Integrity

DATA INTEGRITY

DATA CONFIDENTIALITY

USE CONTROL

DATA FLOW

TIMELY RESPONSE TO EVENTS

RESOURCE AVAILABILITY

ACCESS CONTROL

Cybersecurity is no longer a question of competitive advantage or even minimizing damage.

It is a fundamental requirement for doing business today.

Here are the seven essential pillars for improving it:

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Seven pillars to strengthen cybersecurity

Cybersecurity

Protection of component-generated confidential

or sensitive nature information, whether at rest  
or in transit.

Also, protection of data to avoid hackers who aim  
to break in.

Data regarding energy profiles and usage could  
provide information into confidential Railway  
operations.

Data Confidentiality

DATA CONFIDENTIALITY

USE CONTROL

DATA INTEGRITY

DATA FLOW

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Cybersecurity

Cybersecurity is no longer a question of competitive advantage or even minimizing damage.

It is a fundamental requirement for doing business today.

Here are the seven essential pillars for improving it:

Ensure the connection of the device to a segmented network where disconnection strategy, unidirectional gateway, firewall, and demilitarized zones are defined to avoid unnecessary data flow.

Network segmentation is a strategy that can stop a cyberattack from going from one connected system to another (for example, from the electrical communication network to the business network).

Data Flow

DATA FLOW

DATA CONFIDENTIALITY

USE CONTROL

DATA INTEGRITY

TIMELY RESPONSE TO EVENTS

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ACCESS CONTROL

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Detect, identify and respond to security violations by notifying the proper authority, reporting needed evidence of the violation, and taking timely corrective action when incidents are discovered in mission-critical or safety-critical situations.

Timely Response to Events

TIMELY RESPONSE TO EVENTS

DATA CONFIDENTIALITY

USE CONTROL

DATA INTEGRITY

DATA FLOW

RESOURCE AVAILABILITY

ACCESS CONTROL

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Seven pillars to strengthen cybersecurity

Cybersecurity

Ensure the availability of the application or device  
against the degradation or denial of essential  
services.

Resource Availability

RESOURCE AVAILABILITY

DATA CONFIDENTIALITY

USE CONTROL

DATA INTEGRITY

DATA FLOW

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ACCESS CONTROL

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Cybersecurity	
The IEC 62443 standard provides essential guidelines for enhancing the security of	
connected electrical	
distribution systems, including network, control, and safety solutions.	
When selecting partners, it is important that they understand the standard well and	
implement it effectively.	
It's crucial to choose a partner with robust internal processes who can certify that products	
and solutions are	
developed according to well-defined procedures.	
At Schneider Electric, we have dedicated services to support throughout the cybersecurity	
journey.	
SOLUTION PROVIDERS	
SERVICE PROVIDERS	
CONSULTANT	
Find an electrical power distribution specialist with a	
deep understanding of cybersecurity requirements.	
They should:	
• Help you with the risk assessment;	
• Define the levels of security you require, compliant	
with IEC 62443;	
• Provide guidance on implementing best practices	
for cybersecurity.	
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and solutions are	
developed according to well-defined procedures.	
At Schneider Electric, we have dedicated services to support throughout the cybersecurity	
journey.	
CONSULTANT	
SERVICE PROVIDERS	
SOLUTION PROVIDERS	
Choose an electrical system technology provider that has	
adopted the IEC 62443 standard and has a secure	
development lifecycle process in place that:	
• Ensures systems are resilient in case of cyberattack;	
• Provides a formal process to inform and assist	
customers if any security vulnerabilities are discovered;	
• Fully tests and validates the security of all components	
and systems;	
• Demonstrates third-party cybersecurity certification;	
• Delivers customized and flexible solutions that align	
with your business requirements.	
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Cybersecurity

The IEC 62443 standard provides essential guidelines for enhancing the security of connected electrical

distribution systems, including network, control, and safety solutions.

When selecting partners, it is important that they understand the standard well and implement it effectively.

It's crucial to choose a partner with robust internal processes who can certify that products and solutions are

developed according to well-defined procedures.

At Schneider Electric, we have dedicated services to support throughout the cybersecurity journey.

CONSULTANT

SOLUTION PROVIDERS

SERVICE PROVIDERS

Choose partners with the required capabilities:

- A system integrator with deep IT and OT experience including cybersecurity within the context of critical operational systems
- Cybersecurity services that can deliver quick response to help assess and recover from a cyberattack.

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Certified secure system architecture  
according to IEC 62443-3-3 with  
documented processes and  
solutions for a secure system.  
Cybersecurity system configuration  
software for consistent security  
policy deployment.  
Consulting services from design,  
implementation, operations and  
maintenance to tailor your security  
solutions to your strategy and  
budget.

Our solutions to support cybersecurity journey  
Cybersecurity

At Schneider Electric, we can:

- Provide a selection of cybersecurity certified products
- Provide certified system architectures and solutions
  - Deliver lifecycle services

Lifecycle services Certified products Certified systems & solutions

- Cybersecurity

Learn more about:

Certified products developed  
according to IEC 62443  
functional requirements with  
Secure Development Lifecycle  
processes.

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Governments are committing to carbon neutrality

by 2050, leading to new regulations promoting sustainability: ESG reporting is becoming crucial.

The Corporate Sustainability Reporting Directive (CSRD) expands disclosure requirements to nearly 50,000 companies, including those outside the EU.

This enhances transparency and accountability.

Consumers demand sustainable practices, with a rise in repairing, reselling, and reusing products.

However, greenwashing remains a challenge, as some companies make unsubstantiated sustainability claims. Regulators are cracking down on false claims, emphasizing the need for credible and verifiable environmental data.

Consumer Expectations and

Greenwashing Risks

The need to address ESG regulations

(ESG = Environmental, Social, and Governance)

At Schneider Electric, we have deployed an Environmental Data Program to address this need.

Discover more next page

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 Next-level transparency for better-informed product choices  
 Environmental Data Program  
 The Environmental Data Program is a framework for how we,  
 at Schneider Electric, measure, categorize, and compare the  
 environmental attributes and footprint of our products.  
 Using a rigorous, fact-based methodology, the program  
 provides environmental data from across the product lifecycle.  
 Use Better: How sustainable a product is,  
 including environmental footprint, materials and  
 substances, packaging, and energy efficiency.  
 Use Longer: How a product's lifetime can be  
 effectively extended in terms of repairability and  
 updatability.  
 Use Again: How a product can be reused, from  
 dismantling and remanufacturing to recyclability  
 and manufacturer take back.  
 With this transparent, fact-based data,  
 customers and partners are empowered to  
 make conscious environmental choices and  
 accurately evaluate and report on sustainability  
 performance.  
 All our hardware offers have an associated  
 environmental data available on se.com product  
 pages.  
 • Schneider Electric Environmental Program  
 Learn more about:  
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Urban Transportation: Europe	
Customer Stories The objective of this section is to:	
• Showcase our solutions provided across globe in the Railway and Urban Transportation sectors, addressing our customers' challenges and key needs.	
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### Urban Transportation: Europe

#### Solution Provided

#### Railway: A Leading Railway Operator in Europe

Manage and operate efficiently a country-wide network:

- Nearly 6.000 km mainlines railway network with almost 340 electrical substations;
- Nearly 4.000 km of reliable high speed national rail network with almost 175 traction electrical facilities.

#### Services

- Maintenance services: corrective and preventive
  - Engineering and electrical substation design
  - Cybersecurity

#### Edge Control

- AVEVA System Platform for energy and building management at Control Center level
- EcoStruxure Power Automation System as the substation automation solution
- EcoStruxure Power Monitoring Expert for power management with Power Quality improvements

#### Connected products

- AC MV Panels for traction network: 25 kV AC high speed and 3.3 kV DC mainlines
  - Cabinets for auxiliary power line
- Overhead line disconnectors (OHL): 25 kV AC high speed and 3.3 kV DC mainlines
- PowerLogic T500 (formerly Saitel) for data acquisition and concentration
- Building Management System for Passenger Stations
  - Tunnel Automation System

#### Customer Challenges

- Real-time single view of the national rail network, through integrated main and back-up control centers
- Optimized energy through integrated monitoring and energy management systems

#### Customer Benefits

Public Solution Provided for a Leading Railway Operator in Europe

Apps,  
analytics,  
and services

Edge  
Control  
Connected  
products

AVEVA  
 System Platform  
 EcoStruxure  
 Power Monitoring  
 Expert  
 EcoStruxure  
 Power Automation  
 System  
 Cybersecurity  
 Consulting  
 Digitalization Consulting  
 Electrical Engineering  
 Maintenance Services  
 Commissioning and Training  
 MV switchgear, control units, protection relays, power meters, overhead line controllers  
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 Urban Transportation: Europe

## Customer Challenges

### Urban Transportation: Brookville Smart Energy Bus Depot in US

- Electrification

Converting municipal bus fleet to electric

- Resilience

Extreme weather and extended past power outages

- Sustainability

GHG reduction targets of 80% by 2027 and 100% by 2035

## Services

- EcoStruxure Microgrid Advisor implementing:
  - Tariff Management,
  - Self-consumption
  - Demand charge reduction
- EcoStruxure Power Advisor for power management with Power Quality improvements
- Edge Control
- EcoStruxure Power Operation for power management
- Load Management System for optimizing the charging process from technical and economical point of view
- EcoStruxure Microgrid Operation to integrate removable energy and manage the potential islanded situation from the grid
- Connected products
- EV Charger as main charging element to provide energy to the bus fleet
- Battery Storage System to store energy and help in the optimization of the charging process
- Energy Control Center, integrating all LV equipment needed

## Solution Provided

### Watch now

## Customer Benefits

- 44 buses transitioning from diesel to electric, and powered by on-site low-carbon energy
- 62% of reduced lifetime emissions expected from the microgrid (equivalent to 155,000 tons of GHG)
- 99.9% resilience and reliability of operations, sized to handle peak demand

## Customer Benefits

Public Solution Provided for Brookville Smart Energy Bus Depot in the US

Apps,  
analytics,

and services  
Edge  
Control  
Connected  
products  
Energy  
Control Center  
Battery  
Storage System  
EV  
Charger  
Charge Pilot  
Controller  
EcoStruxure  
Power Operation  
EcoStruxure  
Microgrid Operation  
Load  
Management  
System  
EcoStruxure  
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Urban Transportation: A Leading Metro Operator in Europe	
Services	
• ETAP eTraX Simulation Engine for:	
- Modeling, design, and analysis	
- Predictive simulation of power networks	
- Operator training simulation (OTS)	
Edge Control	
• AVEVA System Platform to operate energy	
systems and passenger stations from the	
control center level	
• Modicon M580 to automate energy systems and	
passenger stations	
Connected products	
• MV panel solutions: RM6 and SM AirSeT	
• PowerLogic P5 to implement electrical	
protection functions	
• Modicon M380 to implement basic automation	
and information acquisition	
Customer Benefits	
• Centralize view for informed decision-making in energy	
management and passenger stations.	
• Improve safety and operational efficiency with end-to-end	
visibility across facilities.	
• Facilitate seamless integration with legacy and modern	
systems.	
Customer Challenges	
• Improvement of operational efficiency with new	
extended remote operation capabilities.	
• Open platform integrating multiple external systems with	
many certified system integrators.	
• Enhanced modeling, design, analysis, operation	
planning, predictive simulation and automation services	
enabled by ETAP real-time solution.	
Customer Benefits	

Public Solution Provided for Leading Metro Operator in Europe

Apps,  
analytics,  
and services  
Edge  
Control  
Connected  
products  
Simulation Engine  
Modicon  
M580  
SM AirSeT  
RM6 (SeT series)  
LV  
Switchgear  
EcoStruxure  
Power Automation  
System  
PowerLogic  
P5  
Modicon  
M340

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Design Guide

Reference Documents

Digital Applications for Large Buildings and Critical Facilities

The Digital Applications Design Guide provides comprehensive details on the building blocks of EcoStruxure Power: the IoT applications are driven by a software layer to control the traditional electrical distribution infrastructure.

Developed to help engineering consultants and designers, this guide is an invaluable resource for specifying, designing and prescribing EcoStruxure Power architectures capable of performing one or more of the business-driven applications described within.

Access the Design Guide online from the Landing page (IEC/NEMA)

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eConversion  
Premium protection and sustainability  
for highly critical applications

A unique high-efficiency mode  
available for Galaxy V-series UPSs  
se.com

The next step in your  
sustainability journey

eConversion mode: the unbeatable combination of power quality and efficiency  
Protect power to your load, reduce your electricity consumption, and meet your  
sustainability goals with up to 99%

efficient, Class 1-compliant eConversion mode for Galaxy V-series UPSs.

This patented high-efficiency mode achieves Class 1 categorization (the highest protection  
class), equaling

Double Conversion, the legacy default operating mode of 3-phase UPSs. In eConversion  
mode, the inverter  
operates continuously, ensuring that if power fluctuates, your UPS can protect the load with  
no transfer time.

eConversion mode also recharges batteries and provides power factor correction and  
harmonics compensation,

making it a versatile solution for protecting both IT and non-IT loads.

Operating at up to 99% efficiency isn't just good for the environment, it's good for your  
balance sheet. Within

10 years, the electricity savings of operating your UPS in eConversion typically equals up to  
3x the price of

the UPS. Delivering premium power protection and optimized total cost of ownership,  
eConversion is both the  
recommended operating mode for your Galaxy V-series UPS and an effortless step toward a  
more profitable  
business and a more sustainable world.

## 2 eConversion

Third-party certified performance  
eConversion is the first UL-verified  
high efficiency mode. It has passed  
the rigorous testing of this 3rd-party,  
industry-leading certification agency.

### Class 1 protection

Choose eConversion mode with  
confidence; its performance has  
been certified Class 1 per IEC ®  
62040-3, the same class as Double  
Conversion.

Excellent load protection,  
including patented zero-break  
transfer design

The UPS continues to deliver  
input power factor correction,

harmonic filtering, and no-break  
transfer to Double Conversion  
mode or battery operation.

Maximum availability,  
third-party certified

Enjoy the highest energy efficiency available today without sacrificing load protection. Every

Galaxy V-series UPS

includes eConversion mode and delivers these benefits:

eConversion meets Class 1 of IEC 62040-3: zero-break  
transfer during power outage.

1000.11 10

Nominal Value (Voltage %)

100%

80%

60%

40%

20%

0%

-20%

-40%

-60%

-80%

-100%

1,000

Overvoltage transient limit

Undervoltage transient limit

+10%

-10%

Transient duration in milliseconds (ms)

eConversion

Over 10 years of field deployment

Since its launch in 2014, eConversion  
has been successfully deployed all  
over the world. Join thousands of  
customers who use it daily to protect  
their critical loads.

Continuously charging batteries

With eConversion mode, your batteries  
are ready when you need runtime.

Ideal for IT and non-IT applications

- Data centers
- Factories
- Commercial offices
- Transportation

- Hospitals

Sustainably reduce your operating costs

Using eConversion mode achieves 99% efficiency, which provides significant savings every year on your electricity bill. Compared to Double Conversion, the savings are typically equivalent to up to 3 times the UPS acquisition price after 10 years.

Optimize your energy consumption

eConversion power savings accrue fast. For example, Galaxy VL with eConversion mode conserves every year as much power as the electricity generated by 30 rooftop solar installations, equivalent to the electricity required to recharge 50 electric cars.

Up to 3x reduction in electricity use

4

= =

1x 31x 53x

Galaxy VL in

eConversion

Rooftop solar

installations

Cars

powered

\$\$\$\$

UPS Price

+ Electricity

Electricity

savings

= up to 3x

UPS price

\$\$\$

\$\$

\$

0

Year 1 Year 5 Year 10

eConversion

99% efficiency

Double Conversion eConversion

Double Conversion

97% efficiency

Total Cost of Ownership, optimized

UPS eConversion savings over 10 years

UPS kW rating Electricity

savings\* Carbon emissions

(metric tons) savings Equivalent solar  
rooftop production Cars  
powered

Galaxy VS 150 kW \$41,000 135 10 16

Galaxy VM 225 kW \$73,000 243 17 28

Galaxy VL 500 kW \$146,000 484 31 53

Galaxy VXL 1250 kW \$394,200 1314 88 150

Galaxy VX 1500 kW \$684,000 2300 154 263

\*Model dependent; based on a market electricity price: \$0.15 /kWh and CO2 emissions  
factor of

0.5 kg/kWh. The annual electricity and carbon emissions savings are done by comparing the  
UPS

efficiency in Double Conversion mode to its efficiency in eConversion mode.

Carbon emissions are calculated based on the world average reported by the International  
Energy Agency (IEA):

<https://www.iea.org/reports/global-energy-co2-status-report-2019/emissions>

Calculate your efficiency and carbon emissions savings using the eConversion vs Double  
Conversion calculator, using this link or the QR code on page 6:

[https://www.se.com/ww/en/work/solutions/system/s1/data-center-and-network-systems/  
trade-off-tools/econversion-vs-double-conversion-calculator/  
eConversion](https://www.se.com/ww/en/work/solutions/system/s1/data-center-and-network-systems/trade-off-tools/econversion-vs-double-conversion-calculator/eConversion)

A unique combination

eConversion, Double Conversion, or ECO mode? A comparative study

For decades, Double Conversion has been used as the default mode in 3-phase UPSs. The  
main

disadvantage is the very high amount of electricity used 24 hours a day, 365 days a year to  
permanently

regulate the output with a very tight +/-1% voltage tolerance. The cost of electricity used to  
perform permanent

regulation typically represents up to 3x the UPS price over 10 years, while permanently re-  
creating a perfect

sinewave has no extra benefit to the load as even the most critical loads are insensitive to a  
+/-10% voltage.

Legacy 3-phase 'Default' mode Legacy 'High-efficiency' mode

Most important for the availability of critical loads is the no-break transfer, certified by Class  
1 protection

(the highest category). In eConversion, the load is powered by the grid as long as it is within  
tolerance, but

the inverter is kept operating in parallel. This ensures a no-break transfer in case of an  
outage, surge, or short

circuit, and ensures third-party certified, Class 1 output, which denotes the highest  
availability.

In comparison, using ECO mode (the legacy high-efficiency mode) reduces load availability  
and is therefore

not a preferred mode of operation for applications requiring maximum protection.

Double Conversion eConversion ECO mode

Voltage fluctuation «««

Frequency fluctuation «««

Recharge batteries «««

No transfer time «««

PF Correction «««

Protection class Class 1

Efficiency 96-97%

Voltage fluctuation ««

Frequency fluctuation ««

Recharge batteries «««

No transfer time «««

PF Correction «««

Protection class Class 1

Efficiency 99%

Voltage fluctuation ««

Frequency fluctuation ««

Recharge batteries Option

No transfer time No

PF Correction No

Protection class Class 3

Efficiency 99%

Bypass switch Bypass switch Bypass switch

Battery Battery Battery

DC/DC DC/DC DC/DC

AC in AC in AC in

M2 M2 M2

M1 M1 M1

AC in AC in AC in Load Load Load

Inverter Inverter Inverter PFC rectifier PFC rectifier PFC rectifier

May be on to

allow battery

recharge

Calculate your savings

6

Use our eConversion vs Double Conversion Calculator to quickly assess your potential energy savings, operating cost optimization, and CO2 emissions reduction by comparing the cost of running your Galaxy

V-series UPS in eConversion mode vs Double Conversion mode.

Scan this QR code with your phone camera, or access the calculator from the Schneider

Electric Data Center

Trade Off Tools™

Web page: <https://www.se.com/ww/en/work/solutions/system/s1/data-center-and-network->

[systems/trade-off-tools/econversion-vs-double-conversion-calculator/](https://www.se.com/ww/en/work/solutions/system/s1/data-center-and-network-systems/trade-off-tools/econversion-vs-double-conversion-calculator/)

If you have site-specific questions, our trained Field Service Representatives can perform a technical assessment of your site before you activate eConversion mode. To learn more, contact your Schneider Electric representative.

On-screen savings meter

If you already have a Galaxy V-series UPS, start using eConversion mode and watch the savings add up!

eConversion

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To learn more about eConversion mode, contact your Schneider Electric representative or visit <https://www.se.com/ww/en/work/solutions/eConversion-high-efficiency-UPS-mode>

About Schneider Electric: At Schneider Electric, we believe access to energy and digital is a basic

human right. We empower all to make the most of their energy and resources, ensuring Life Is On

everywhere, for everyone, at every moment. We provide energy and automation digital solutions for

efficiency and sustainability. We combine world-leading energy technologies, real-time automation,

software and services into integrated solutions for Homes, Buildings, Data Centers, Infrastructure,

and Industries. We are committed to unleash the infinite possibilities of an open, global, innovative

community that is passionate about our Meaningful Purpose, Inclusive and Empowered values.

[www.se.com](https://www.se.com)

3-Phase Uninterruptible Power Supply  
(UPS) Secure Power Portfolio

[www.se.com](https://www.se.com)

Public

2

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Schneider's purpose is to empower all to make the most of our energy and resources, bridging progress and sustainability for all. We call this Life Is On. Our mission is to be your digital partner for Sustainability and Efficiency.

Schneider Electric is a world leader in power protection, solving today's energy challenges while setting the standard for quality and innovation with fully integrated solutions, enterprise-wide networks, data centers, mission-critical systems, and industrial/manufacturing processes.

##### Overview

Empowering all to make the most of our energy and resources, bridging progress and sustainability for all.

##### 3

##### Public

##### 4

## Our Portfolio

Fully integrated, end-to-end 3-phase UPS solutions help maintain your enterprise-wide networks, data centers, mission-critical systems, and industrial manufacturing processes.

Our global portfolio of world-class products and services uniquely combines to offer end-to-end critical power solutions, providing customers with robust power protection, anytime/anywhere visibility, and peace of mind with EcoStruxure IT software and flexible service plans throughout the life cycle of their installations.

### Galaxy V Series UPSs

Maximize your availability and sustainability and optimize your total cost of ownership. Our modular Galaxy V Series UPSs deliver superior performance in a compact footprint, with up to 99% efficiency in eConversion mode, scalability and internal redundancy options, and Galaxy Lithium-ion battery solutions, making them ideal for the data center or business-critical applications.

### Easy UPS 3-phase UPSs

Quickly deploy power protection that optimizes your capital expenses. Easy UPS 3-phase range UPSs feature robust electrical specifications, ruggedizing features, and a compact, lightweight footprint that are ideal for commercial or industrial applications.

### Modular Data Centers

Schneider Electric 3-phase UPSs are ideal for Modular Data Center applications. Contact your Schneider Electric representative to learn how you can increase your infrastructure capacity while shrinking your infrastructure footprint.

5

## Products

### 3-phase UPSs

#### Galaxy VS

For external batteries: 10-75 kW (208V), 20-150 kW (400V/480V)

With internal smart battery modules: 10-50 kW (208V), 10-100 kW (400V), 20-100 kW (480V)

Sold: Worldwide

6

## SE.com

## Features

### Applications & Segments

- IT
  - Small and medium data centers
  - Business-critical applications
    - Edge
- Commercial and industrial facilities
  - Marine
- Healthcare, Oil & Gas, Transportation, Minerals, Metals, Mining, Power, Grid
- High efficiency in eConversion mode (up to 99%)

- Maximum availability with modular architecture
  - Innovative Live Swap of power modules
- Parallel for capacity or redundancy—up to 4 UPSs
  - Internal redundancy with N+1 power modules
- Flexible modular, classic, & Lithium-ion battery solutions
  - Compact design with optimized footprint
    - Touchscreen display with NMC
  - NMC with Secure Subscription License
    - EcoStruxure connected
    - Green Premium solution
    - Start-up service included

#### Options

- Battery flexibility, including Lithium-ion batteries
- Single and parallel wallmount maintenance bypass panel
  - Classic and Modular Battery Cabinets
- Battery Breaker Box and Battery Breaker Kit
  - IP52/NEMA 12 Kit
  - Seismic kits (OSHDP)
- Network management card embedded with ethernet (NMP) and Modbus
- Galaxy VS 20 kW (480V in, 400V out) up to 80 kW Internal Input Transformer for NAM

#### Overview

Galaxy VS is a highly efficient, modular, simple-to-deploy 3-phase UPS that delivers top performance to edge, small, and medium data centers, as well as critical infrastructure in commercial and industrial facilities.

It offers increased availability, reduced operating costs, and first-class power protection for critical infrastructure.

#### Galaxy VM

For external batteries: 160-200 kVA (400V), 160-225 kVA (480V)

Sold: Worldwide (except Japan)

#### Features

##### Applications & Segments

- Mission-critical environments
  - Medium data centers
- Industrial plants and applications
  - Facility infrastructure
    - Healthcare
  - Telecommunications
- Highly efficient eConversion mode (up to 98.5%)
  - Integrated backfeed protection
- Single-cabinet top and bottom cable entry
  - Full front-service access

- Flexible modular, classic, and Lithium-ion battery solutions
- Large color touch-screen display with built-in NMC
  - 65 kAIC rating standard
  - Compact footprint
  - Smart Power Test (SPoT) mode
  - OSHPD certified cabinets
- Integrated casters for ease of mobility
  - EcoStruxure connected
  - Start-up service included
- Options
  - Classic and Modular Battery Cabinets
    - Management cards
    - Fuse kits
  - Wall-mounted battery breaker boxes
    - Parallel system bypass cabinets
    - Dust filter kits
    - System bypass cabinets
    - 208V transformers
  - Flywheel and Lithium-ion battery compatible
- Network Management Card (AP9640 / AP9641) with Secure NMC Subscription License

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#### Overview

Galaxy VM is a highly efficient, modular 3-phase UPS that seamlessly integrates into medium data centers, industrial, or facilities applications.

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Public

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#### Galaxy VL

##### Applications & Segments

- Mission-critical environments
- Medium and large data centers
  - Colocation facilities
  - Computer rooms
- Edge computing, Internet DC, Cloud computing
- Light industry and commercial buildings
- Infrastructure and transportation

8

For external batteries: 200-500 kW (400V/480V)

Sold: Worldwide

## Overview

Galaxy VL is a highly efficient, scalable 3-phase UPS featuring a modular, redundant design and low TCO for medium and large data centers and mission-critical environments. Minimize your total cost of ownership while expanding your business and maximizing your availability, reliability, and sustainability. With up to 99% efficiency in eConversion mode and fast power expansion with Live Swap, Galaxy VL is the most compact galaxy in the UPS universe. Make your data center or co-location facility more sustainable today.

SE.com

## Features

- Highly efficient eConversion mode (up to 99%)
- Compact design, optimized footprint
  - Innovative Live Swap
- Lithium-ion battery option
  - Parallel for capacity or redundancy—up to 6 UPSs
- Scalable, modular design enables N+1 internal redundancy
- Smart Power Test (SPoT) mode
  - Fault-tolerant design
- Touchscreen display with NMC
- Secure NMC Subscription License
  - Full front-service access
  - EcoStruxure connected
  - Green Premium solution
  - Startup service included

## Options

- Classic battery cabinets
  - SKRU kit
- Remote Centralized Display Box
- Bottom Entry Cabinet 65kAIC Kit
  - Seismic (with option kit)
  - Replaceable dust filters
- Backfeed protection options
  - Battery Breaker Box/Kit
- NMC embedded with ethernet (NMP) and Modbus
- Maintenance bypass cabinets

## Galaxy VX

## Features

#### Applications & Segments

- Mission-critical environments
  - Large/extra-large data centers
    - Industrial applications
    - Facility infrastructure
  - Cloud and Service providers
    - Colocation facilities
  - Finance, semiconductor, and manufacturing environments
  - Telecommunications, Healthcare
    - Highly efficient eConversion mode (up to 99%)
    - Cabinet-level scalability for capacity or redundancy
    - Dual mains input, top and bottom cable entry
  - Parallel for capacity or redundancy — up to 4 UPSs
  - Flywheel and Lithium-ion battery compatible
  - Internal redundancy with N+1 power cabinets
  - Smart Power Test (SPoT) mode
  - Touchscreen display with NMC
    - EcoStruxure connected
    - Startup service included
- Options
- Battery pull box
  - Network Management Card (AP9640 / AP9641 / AP9643) with Secure NMC Subscription License
    - SmartSlot cards
  - Replaceable dust filters
  - Single feed kit

9

For external batteries: 500 scalable to 1500 kW N+1 (400V/480V)

Sold: Worldwide

#### Overview

Galaxy VX is a highly efficient, modular 3-phase UPS scalable from 500 to 1500 kW in a single unit with high performance and flexible operating modes. Its scalability accommodates the changing needs of your rapidly expanding business, and its exceptional performance and abundance of cost-saving features reduce your energy

costs and total cost of ownership. Galaxy VX is the ideal UPS for today's large data centers, cloud and colocation facilities, as well as mission-critical applications.

SE.com

- Parallel cable kit
- Maintenance bypass cabinets
- Classical battery cabinets

Public

10

Galaxy VXL

10

For external batteries: 500-1250 kW (400V)

Sold: All IEC countries worldwide

SE.com

Features

Applications & Segments

- Large and extra-large data centers
- Colocation facilities
- Computer rooms
- Light industry & commercial buildings
- Cloud & Service Provider facilities
  - Semiconductor industry
  - Manufacturing critical line
  - Energy and Chemicals
  - Bank, Finance, Insurance
  - Pre-fabricated systems
- High efficiency eConversion mode (up to 99%)
- Compact design, optimized footprint only 1.2m<sup>2</sup>
  - Innovative Live Swap
- Lithium-ion battery integration
  - EcoStruxure connected
  - Scalable, modular design enables N+1 internal redundancy
- Reliable and fault-tolerant design
  - Sustainable solution
  - Full front access
- Unity power factor @40°C, kVA=kW
  - Touchscreen display with NMC
  - High short circuit level 100kA
- Secure NMC Subscription License

- Smart Power Test (SPoT) mode
  - Startup service included
- Options
  - Battery Breaker Box/Kit
  - Empty Battery Cabinet

#### Overview

Galaxy VXL is a highly efficient, compact, and modular 3-phase UPS with Live Swap. With its industry-leading

compact design, high-density technology, and fault-tolerant architecture, Galaxy VXL maximizes availability,

operational efficiency, and critical load protection while minimizing TCO. This UPS delivers up to 97.5% efficiency

in double conversion mode and up to 99% in eConversion mode, reducing the UPS Carbon emissions by a

factor of two. Galaxy VXL offers proactive asset management services to give you peace of mind anytime,

anywhere. Start-up service is included.

- Galaxy Lithium-ion Battery
  - Cabinets
    - Air filter kit
  - Parallel Communications Kit
  - Seismic kit, and other options

#### Public

11

#### Easy UPS 3S

For external batteries: 10-40 kVA (400V)

With and/or for internal batteries: 10-40 kVA (208V/400V)

Sold: US, Canada, Mexico, and all IEC countries worldwide, except Japan

#### Features

##### Applications & Segments

- Small data centers
- Commercial buildings & light industrial applications
  - Business-critical applications
- Healthcare, Telecommunication, Transportation, Manufacturing facilities
  - Non-IT
- Easy to install and start up; minimal footprint
  - Delivers up to 96% efficiency
- Wide operating temperature range and strong overload protection
  - Replaceable dust filters
- Strong protection against harsh environments with robust electrical specifications
  - Conformal coating

- Easy Loop Test to verify UPS performance before you connect your load
- Parallel for capacity or redundancy—up to 4 UPSs
  - Easy to manage with mimic panel
    - EcoStruxure connected
  - Long life battery string ready
- Options
  - Cold Start kit
- Parallel maintenance bypass, up to 2 units for 400V or 3 units for 208V
- Battery Breaker Box and Battery Breaker Kit
  - Empty battery cabinets
  - Standard 7Ah or 9Ah battery modules
  - NMC with Secure Subscription License
    - Start-up service

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#### Overview

Easy UPS 3S (400V) is an easy to install, use, and service 3-Phase UPS available for external batteries or with and/or for internal batteries designed for small data centers and other business critical applications.

Easy UPS 3S (208V) is an easy to install, use, and service 3-Phase UPS for internal batteries designed for small data centers, commercial buildings, non-IT, and light industrial applications.

SE.com: 400V / 208V

Public

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#### Easy UPS 3M

For external batteries: 60-200 kVA (400V) and 50-100 kVA (208V)

With internal batteries: 60-80 kVA (400V)

Sold: 208V countries of South America and Caribbean Islands, and all IEC countries worldwide, except Japan

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SE.com

#### Features

#### Applications & Segments

- Small and medium data centers and computer rooms
  - Electrical rooms
  - Business-critical applications
  - Commercial buildings
  - Healthcare, Telecommunication, Transportation, Manufacturing facilities
    - Start-up included
- Easy deployment and compact footprint

- Delivers up to 95.5% efficiency
- Wide operating temperature range and strong overload protection
- Strong protection against harsh environments with robust electrical specifications
- Easy Loop Test to verify UPS performance before you connect your load
  - IP20 protection (extra protection with IP30, IP40, and/or IPX2 Option Kits)
    - Replaceable dust filters
  - Parallel for capacity or redundancy—up to 6 UPSs
    - Front and rear access service
  - Easy to manage with touchscreen display
  - Embedded NMC with Subscription License
    - EcoStruxure connected
- Options
  - Parallel and unitary maintenance bypass panel
    - Modular Battery cabinet
  - Classic Battery Cabinets with batteries
    - Empty battery cabinets
  - Battery Breaker Box and Battery Breaker Kit
  - Battery string or high-capacity battery string
    - Lithium-ion battery option

#### Overview

Easy UPS 3M 60-200 kVA (400V) and 50-100 kVA (208V) for external batteries, and 60-80 kVA (400V) with internal batteries is an easy to install, connect, use, and service 3-Phase UPS for small and medium data centers, electrical rooms, and other business-critical applications.

#### Public

13

#### Easy UPS 3M Advanced

For external batteries: 100-250 kW (400V)

Sold: India

#### Features

#### Applications & Segments

- Small and medium data centers
  - Commercial buildings
  - Light industrial applications
- Government & Public Sector Units
  - Healthcare, Telecommunication, Transportation, Retail, Process Automation
- Start-up included to optimizes your system's

- performance, quality, and safety
- Scalable 100 kW to 250 kW for pay as you grow
  - Modular design, enabling easy serviceability
    - Easy deployment and compact footprint
      - Delivers up to 96% efficiency
- Single frame capable up to 250 kW in capacity with Internal N+1 redundancy for up to 200 kW N+1
- Wide operating temperature range and strong overload protection
  - Pluggable Draw In/Out type power module
    - kVA = kW up to 40°C
    - Replaceable dust filters
    - Front and rear access service
- Easy to manage with 7" touchscreen display
  - EcoStruxure connected
  - Made in India enables direct sales to Government, Public Sector Units, and Infrastructure Projects

#### Options

- Power module
- Maintenance Bypass Panel
- Battery Breaker Box and Battery Breaker Kit

13

#### Overview

Easy UPS 3M Advanced—part of the Easy UPS 3-phase range—is an easy-to-install, connect, use, service, and scale 100-250 kW (400V) 3-Phase UPS made in India that is ideal for small and medium businesses, data centers, and other mission-critical applications in India.

SE.com

- Battery Temperature Sensors
- Network Management Card (AP9640 / AP9641) with Secure NMC Subscription License

Public

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#### Easy UPS 3L

For external batteries: 250-600 kW (400V)

Sold: All IEC countries worldwide, except Japan and China

#### Applications & Segments

- Medium and large commercial buildings
  - Light industrial applications
- Computer room and regional data centers
- Healthcare, Telecommunication, Transportation, Financial, Government

- Non-IT

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#### Overview

Easy UPS 3L 250-600 kVA (400V) is an easy to configure, use, and service 3-Phase UPS that delivers high availability and predictability to medium and large commercial buildings and light industrial applications.

SE.com

#### Features

- Easy deployment and compact footprint
  - Delivers up to 96% efficiency
- Power Module for fault-tolerant design
  - Streamlined installation and service
- Protection against harsh environments with robust electrical specifications and ruggedizing features, including conformal coating
  - Replaceable dust filter
- 1+1 redundant UPSs can share a common battery bank, reducing battery costs
  - IP20 (extra protection with IP31 option kit)
  - Smart Test mode optimizes site acceptance testing costs without requiring a load bank
- Parallel up to 5 UPSs for capacity or 5+1 UPSs for redundancy
  - Supports 4+4 redundant configurations
    - Top cable entry
    - EcoStruxure connected
- Embedded NMC with Secure NMC Subscription

#### License

- Start-up service included

#### Options

- Maintenance Bypass Panel
  - Classic Battery Cabinets
  - Empty battery cabinets
- Battery Breaker Box and Battery Breaker Kit
  - Cold Start kit
  - Lithium-ion battery option

#### Public

15

#### Galaxy 3L

For external batteries: 250-600 kW (400V)

Sold: China

#### Features

#### Applications & Segments

- Medium and large data centers, and colocation facilities
  - Commercial and light industrial applications
    - Edge applications and computer rooms
  - Telecommunication, Healthcare, Government
    - Transportation, Manufacturing, Finance
  - Easy deployment and compact footprint
    - Delivers up to 96% efficiency
    - Fault-tolerant design
- Protection against harsh environments with robust electrical specifications and ruggedizing features
- 1+1 redundant UPSs can share a common battery bank, reducing battery costs
  - Top cable entry
  - Replaceable dust filter
  - Embedded Network Management Card
  - IP20 (extra protection with IP31 option kit)
  - Smart Test mode optimizes site acceptance testing costs without requiring a load bank
- Parallel up to 5 UPSs for capacity or 5+1 UPSs for redundancy
  - Supports 4+4 redundant configurations
    - 7-inch display
    - EcoStruxure connected
    - Start-up included

Options

- Maintenance Bypass Panel
- Battery Breaker Box and Battery Breaker Kit
  - Classic Battery Cabinets
  - Empty battery cabinets
  - Cold Start kit

15  
Overview

Galaxy 3L 250-600 kVA (400V) is an easy to configure, use, and service 3-Phase UPS that delivers high availability and predictability to medium and large data centers, commercial buildings, and light industrial applications in China.

SE.com

- Bottom entry Cabinet
- Lithium-ion battery option

Public

16

Easy UPS 3-Phase Modular

For external batteries: 50-250 kW (400V)  
Sold: All IEC countries worldwide, except Japan and China

16

## Overview

Easy UPS 3-Phase Modular 50-250 kW (400V) delivers robust power protection and availability in a capital-expenditure-friendly package. It is easy to select, quote, install, and maintain, with modular, redundant, scalable options and Live Swap modules in a compact footprint.

SE.com

## Features

### Applications & Segments

- Easy to select, configure, start up, use, and service
- Up to 96% efficiency in double conversion mode
- Third-party verified Live Swap functionality for fast MTTR and expansion with no scheduled downtime
- Add Live Swap power modules as demand grows
- Modular design with 50 kW power module enables N+1 redundancy to increase availability
  - Scalable design: pay as you grow
- Up to 250 kW N+1 in a black one-rack design to conserve valuable real estate
  - Unity power factor @40°C
  - EcoStruxure connected for peace of mind anytime, anywhere
- Parallel 4+0, increasing power capacity to 1 MW
  - Neutral Lithium-ion Function
    - Start-up service included
    - Bottom Entry Cabinet
    - Empty Battery Cabinet
  - Battery Breaker Box and Battery Breaker Kit
    - Maintenance Bypass Panel
    - Parallel Communications Kit
  - Redundant Intelligence Module
    - Lithium-ion battery option
    - Classic Battery Cabinet
- Network Management Card (AP9640 / AP9641) with Secure NMC Subscription License
- Other options: Depth Adapter, Backfeed Kit, Wide Seismic Kit, Battery Temperature Sensor
  - Small and medium data centers
    - Telecommunication
    - Transportation
    - Healthcare

- Process Automation Options

- Commercial buildings

- Retail

Public

17

Galaxy PX UPS

100-250 kW (400V)

Sold: China

Features

Applications & Segments

- Simple to select, configure, start up, use, and service
  - Up to 96% efficiency in double conversion mode
  - Third-party verified Live Swap functionality for fast MTTR and expansion with no scheduled downtime
  - Compact footprint with 10-inch touchscreen display
- Modular design with 50 kW power module enables N+1 redundancy to increase availability
  - Parallel 4+0, increasing power capacity to 1 MW
  - Up to 250 kW N+1 in a black one-rack design to conserve valuable real estate
  - Scalable design: optimize capex, pay as you grow
    - Unity power factor @40°C
  - EcoStruxure connected for peace of mind anytime, anywhere
  - Neutral Lithium-ion Function
    - Start-up service included

Options

- Bottom Entry Cabinet
  - Depth Adapter
- Neutral Disconnection Kit for 250 KW
  - Battery Temperature Sensor
  - Parallel Communications Kit
  - Lithium-ion battery option
- 600mm wide Seismic Kit for 250 kW
  - Backfeed Kit 250 kW
  - Network Management Card
- Redundant Intelligence Module

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Overview

Galaxy PX 100-250 kW (400V) UPS delivers robust power protection and availability in a capital-expenditure-friendly package. It is simple to select, quote, install, and maintain, with modular,

redundant, scalable options,  
and Live Swap modules in a compact footprint.

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- Small & medium data centers
  - Telecommunication
  - Transportation
  - Healthcare
- Process Automation • Commercial buildings
  - Retail

Symmetra PX

400V: 16-500 kW with Symmetra PX 48 All-in-One, 96/160, & 250/500

208V: 10-100 kW with Symmetra PX 20, 40, & 100

480V: 100-500 kW with Symmetra PX 100 & 250/500

Sold: Worldwide

250/500

20 40 48 AIO

96/160 100

250/500

18

SE.com

Features

Applications & Segments

- Data closet
- Small, medium, and large data centers
- Line up and match NetShelter form factor
- Configurable for N+1 internal redundancy
  - Redundant intelligent modules
  - Scalable power capacity
- Modular power, battery, bypass, and intelligent control modules
- Parallel up to 4 UPSs (Symmetra PX 250/500 only)
  - Dual mains input, top or bottom feed
  - Embedded power distribution (PX20, 48)
    - EcoStruxure connected
- Network Management Card with Secure NMC

Subscription Licenses

- Start-up service included

Options

- Secondary network management card (HTTP/Telnet/SNMP)
- Seismic kits (OSHDP)
- Battery breaker enclosure

Overview

Symmetra PX is a high performance, right-sized, modular, scalable, 3-phase UPS that offers power protection with high availability and efficiency for small, medium, and large data centers and mission-critical environments. Made up of dedicated and redundant modules, this architecture can scale power and runtime as demand grows or as higher levels of availability are required.

- Extended runtime battery frames
- Classic battery cabinets: PX100, 96/160, 250/500
- Lithium-ion battery option for Symmetra PX 250/500
- High-density zones of large data centers
  - Mission-critical environments
  - Maintenance bypass cabinets with distribution: PX40, 100, 96/160, 250/500
  - Configurable power distribution: PX20, 40, 100
  - Modular power distribution: PX48, 96/160, 100

#### Galaxy PW 2nd Gen Features

##### Applications & Segments

- Petroleum Petrochemical Gas
  - Metallurgy
  - Power Plant
  - Medical
- Semiconductor
- Transportation
- Food & Beverage
  - Mining
  - Manufacturing
- Supports dual input
- Overload capacity: 125% 10 min; 150% 1 min
- Parallel up to 3+1 (4+0)
  - ISTA 2B
- Robust design for harsh environments
  - Phase rotation check
- Standard protection class: IP31

- Operating temperature: 0-40°C
  - Supports DC cold start
  - Designed for easy service
  - Start-up service included

#### Options

- AP9547 Network Management Card with Secure NMC Subscription License
  - Replaceable dust filters
- Parallel Communications Kit
  - Backfeed Kits

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10-200 kVA (400V) transformer-based UPS

Sold: Europe, Middle East & Africa, Pacific, and Greater China

#### Overview

Galaxy PW 2nd Gen is a 10-200 kVA (400V) transformer-based UPS for industrial applications.

The DC busbar voltage covers 220VDC and 384VDC, and uses a reliable 6-pulse or 12-pulse SCR rectifier.

SE.com

- Cable Adapter Kits for Galaxy

Pwi

- IP42 Kit (ETO)

Products

3-phase UPSs

Products

3-phase Lithium-ion Battery Cabinets

20

Public

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Galaxy Lithium-ion Battery Cabinets

Features

Applications & Segments

- Data centers, colocation, computer rooms
- Edge computing, Internet DC, cloud computing
  - Computer rooms
- Light industrial and commercial buildings
  - Infrastructure and transportation
- Telecommunications and networking
  - Critical power infrastructures
  - Emergency lighting
- UP9540A fire tested compliance
- 67Ah LMO/NCM battery system
- Double your battery life vs. VRLA solutions

- Up to 70% more compact footprint frees up floor space for revenue-generating equipment
- Boost availability with 2-3x faster recharge rates than VRLA solutions
- Built-in 3-level battery management system (BMS)
  - Green Premium solution
- Aesthetic match with Galaxy V Series UPSs
  - Self feeding SMPS simplifies installation
- Fast, simple installation — cabinet ships pre-assembled, except battery modules, and rolls quickly into place
- Enhance employee protection with modular touch-safe design, breaker covers, and built-in fuse protection at the battery cell and cabinet level
  - Seismic kit
  - EcoStruxure connected
- Start-up service options available

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For Galaxy VS, VM, VL, VX, VXL; Symmetra PX 250/500; Symmetra MW; Easy UPS 3M; Easy UPS 3L/Galaxy 3L; Easy UPS 3-Phase Modular; and Galaxy PX

Sold: Worldwide

#### Overview

A Galaxy Lithium-ion Battery Cabinet are compact, lightweight, long-lasting, and sophisticated energy storage solution for Galaxy V series and Easy 3-phase UPSs in data centers, industrial processes, and critical infrastructures.

This UL9540A-compliant battery solution reduces battery footprint and weight by up to 70%, allowing more effective use of space. Lithium-ion batteries reduce total cost of ownership, both by doubling battery life and by operating at higher temperatures, reducing cooling requirements.

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#### Products

#### 3-phase IT Power Distribution

Public

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#### Power Distribution Units (PDUs)

#### Features

#### Applications

- Small, medium, and large data centers
- Colocation facilities

- Compartmental design simplifies asset access allocation
- Meets the demanding scalability needs of any data center of any size
- Factory installed and tested Square D breaker panel configured to meet the unique needs of your site
  - Easy to install and service with top and bottom cable entry
  - Low total cost of ownership
  - Seismic cabinet (OSHDP)
  - 7-inch display interface
  - EcoStruxure connected

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#### Overview

Power Distribution Units are reliable, scalable, and intelligent high-density power distribution solutions ideal for installation in the electrical rooms of data centers.

SE.com

400 & 500 kVA (480V)

Sold: US, Central America

#### Options

- Copper or aluminum transformers
  - Main input switch or breaker
    - Main output breaker
    - Advanced metering
- Wide range of 250 Amp, 400 Amp, and 600 Amp branch breaker options from Schneider Electric's PowerPact J- and L-frame breaker series
  - EPO

- Cloud service providers
- Industrial applications

400 & 500 kVA

(Aluminum) and

400 kVA (Copper)

500 kVA

(Copper)

Public

24

Galaxy RPP

Features

Applications

- Data centers • Colocation facilities • Cloud service providers
  - Compact footprint and easy front-access design
  - Supports installation against walls, back-to-back,

or in your EcoStruxure Pod Data Center

- Flexible configuration, with factory installed and tested Square D breaker panels configured to your site requirements
- Meets the demanding scalability needs of any large data center
- PowerLogic Branch Circuit Power Meter monitors single or dual feed installations
- Compartmental design simplifies asset access allocation
  - Top and bottom cable entry
- Compatible with all Schneider Electric Power Distribution Units
  - 7-inch touchscreen display
  - EcoStruxure connected

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#### Overview

Galaxy RPP (Remote Power Panels) 250 and 400 Amp (120V/208V) offers highly configurable, highly modular, high-density row-level power distribution for data centers and colocation facilities.

SE.com

250 & 400 Amp (120V/208V)

Sold: US, Canada, Central America

#### Options

- L-frame or J-frame main input breakers
    - NP, NQ, or IP2X panelboard
  - QO, QOB, or EDB distribution breakers
    - Surge protection devices
  - Start-up service options available
- Configurable and Modular Power Distribution Units
- Top or bottom cable entry (60/150 kW PDU)
    - Flexible configure-to-order options
    - Factory assembled and tested
      - Scalable
      - Modbus supported
      - Integrated monitoring
        - Network enabled
      - No side access required
      - Preconfigured cord sets
  - Compatible with StruxureWare Data Center Expert
    - Branch circuit monitoring
  - Power distribution modules with locking connectors (Modular)

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## Features

### Applications

- Small, medium, or large data centers

### Overview

Modular Power Distribution Units (PDUs) mitigate the need to predict the future requirements and configurations of your data center.

Configurable Power Distribution Units bring agility, availability, and speed of deployment to your data

center. Our factory-tested power distribution units are built to your exact specifications, support overhead or

underfloor distribution, and feature a convenient, portable rack form factor.

### Options

120/208/230/400/480/600V: 72-277 kW (Modular)

208V/480V/600V: 40-150 kW (Configurable)

Sold: Worldwide; product availability varies by region

### Modular Configurable

- Shielding troughs Startup service

SE.com: Configurable and Modular

Upsilon Static Transfer Switches

30-630A standard; 800-1250A on request

Sold: All IEC regions worldwide

- Industrial applications
  - Data centers
  - Telecommunication centers
  - Infrastructure
- Simplifies installation and maintenance while minimizing space requirements
- Independent control boards, dual cooling systems, and power supplies ensure high reliability performance
- Small footprint reduces required floor space
- Text and mimic diagrams display modes of operation, system parameters, and alarms
- Allows isolation of a source for maintenance without interrupting power to the protected loads

### Options

- Communication: JBus/Modbus card (supplied as standard), status information card (supplied as standard)
  - Open frame version

### Overview

Upsilon Static Transfer Switches (STS) provides true redundancy and exceptional high reliability for automatic

power supply transfer to a range of equipment from two independent and redundant power sources. Static Transfer Switches automatically transfer power to a stable alternate source in less than 4ms under normal operating conditions. Even under extreme conditions, such as 180 degrees out of phase, the STS will have detection and automatic transfer times that are up to 10 times faster than many other switches.

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- PDU (36 16A circuit breakers incorporated in the H = 1900 cell, up to 100 A)
- Connection at the top of the unit

Features

Applications & Segments

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Key Applications and Segments by Product

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IT

Small data centers

Medium data centers

Large data centers

Colocation facilities

Cloud computing

Commercial facilities

Industrial facilities

Healthcare

Transportation

Telecommunications

Energy & Chemical

Metal, Minerals, and Mining

Consumer Packaged Goods

Semi Conductor

Galaxy VS

Galaxy VM

Galaxy VL

Galaxy VX

Galaxy VXL

Easy UPS 3S

Easy UPS 3M

Easy UPS 3M Advanced

Easy UPS 3L

Galaxy 3L

Easy UPS 3-Phase Modular

Galaxy PX

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France

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Schneider's purpose is to empower all to make the most of our energy and resources, bridging progress and sustainability for all. We call this Life Is On. Our mission is to be your digital partner for Sustainability and Efficiency.

Schneider Electric is a world leader in power protection, solving today's energy challenges while setting the standard for quality and innovation with fully integrated solutions, enterprise-wide networks, data centers, mission-critical systems, and industrial/manufacturing processes.

#### Overview

Empowering all to make the most of our energy and resources, bridging progress and sustainability for all.

3

Public

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Our Portfolio

Fully integrated, end-to-end 3-phase UPS solutions help maintain your enterprise-wide networks, data centers, mission-critical systems, and industrial manufacturing processes.

Our global portfolio of world-class products and services uniquely combines to offer end-to-end critical power solutions, providing customers with robust power protection, anytime/anywhere visibility, and peace of mind with EcoStruxure IT software and flexible service plans throughout the life cycle of their installations.

Galaxy V Series UPSs

Maximize your availability and sustainability and optimize your total cost of ownership. Our modular Galaxy V Series UPSs deliver superior performance in a compact footprint, with up to 99% efficiency in eConversion mode, scalability and internal redundancy options, and Galaxy Lithium-ion battery solutions, making them ideal for the data center or business-critical applications.

Easy UPS 3-phase UPSs

Quickly deploy power protection that optimizes your capital expenses. Easy UPS 3-phase range UPSs feature robust electrical specifications, ruggedizing features, and a compact, lightweight footprint that are ideal for commercial or industrial applications.

Modular Data Centers

Schneider Electric 3-phase UPSs are ideal for Modular Data Center applications. Contact your Schneider Electric representative to learn how you can increase your infrastructure capacity while shrinking your infrastructure footprint.

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Products

3-phase UPSs

Galaxy VS

For external batteries: 10-75 kW (208V), 20-150 kW (400V/480V)

With internal smart battery modules: 10-50 kW (208V), 10-100 kW (400V), 20-100 kW (480V)

Sold: Worldwide

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Features

Applications & Segments

- IT
- Small and medium data centers
- Business-critical applications
- Edge
- Commercial and industrial facilities
- Marine

- Healthcare, Oil & Gas, Transportation, Minerals, Metals, Mining, Power, Grid
- High efficiency in eConversion mode (up to 99%)
- Maximum availability with modular architecture
  - Innovative Live Swap of power modules
- Parallel for capacity or redundancy—up to 4 UPSs
  - Internal redundancy with N+1 power modules
- Flexible modular, classic, & Lithium-ion battery solutions
  - Compact design with optimized footprint
    - Touchscreen display with NMC
  - NMC with Secure Subscription License
    - EcoStruxure connected
    - Green Premium solution
    - Start-up service included

#### Options

- Battery flexibility, including Lithium-ion batteries
- Single and parallel wallmount maintenance bypass panel
  - Classic and Modular Battery Cabinets
- Battery Breaker Box and Battery Breaker Kit
  - IP52/NEMA 12 Kit
  - Seismic kits (OSHDP)
- Network management card embedded with ethernet (NMP) and Modbus
- Galaxy VS 20 kW (480V in, 400V out) up to 80 kW Internal Input Transformer for NAM

#### Overview

Galaxy VS is a highly efficient, modular, simple-to-deploy 3-phase UPS that delivers top performance to edge, small, and medium data centers, as well as critical infrastructure in commercial and industrial facilities.

It offers increased availability, reduced operating costs, and first-class power protection for critical infrastructure.

#### Galaxy VM

For external batteries: 160-200 kVA (400V), 160-225 kVA (480V)

Sold: Worldwide (except Japan)

#### Features

##### Applications & Segments

- Mission-critical environments
  - Medium data centers
- Industrial plants and applications
  - Facility infrastructure
  - Healthcare
  - Telecommunications
- Highly efficient eConversion mode (up to 98.5%)

- Integrated backfeed protection
- Single-cabinet top and bottom cable entry
  - Full front-service access
- Flexible modular, classic, and Lithium-ion battery solutions
- Large color touch-screen display with built-in NMC
  - 65 kAIC rating standard
  - Compact footprint
- Smart Power Test (SPoT) mode
  - OSHPD certified cabinets
- Integrated casters for ease of mobility
  - EcoStruxure connected
  - Start-up service included
- Options
  - Classic and Modular Battery Cabinets
    - Management cards
    - Fuse kits
  - Wall-mounted battery breaker boxes
    - Parallel system bypass cabinets
      - Dust filter kits
    - System bypass cabinets
      - 208V transformers
  - Flywheel and Lithium-ion battery compatible
  - Network Management Card (AP9640 / AP9641) with Secure NMC Subscription License

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### Overview

Galaxy VM is a highly efficient, modular 3-phase UPS that seamlessly integrates into medium data centers, industrial, or facilities applications.

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Public

## 8

### Galaxy VL

#### Applications & Segments

- Mission-critical environments
- Medium and large data centers
  - Colocation facilities
  - Computer rooms
- Edge computing, Internet DC, Cloud computing
- Light industry and commercial buildings
- Infrastructure and transportation

For external batteries: 200-500 kW (400V/480V)

Sold: Worldwide

### Overview

Galaxy VL is a highly efficient, scalable 3-phase UPS featuring a modular, redundant design and low TCO for medium and large data centers and mission-critical environments. Minimize your total cost of ownership while expanding your business and maximizing your availability, reliability, and sustainability. With up to 99% efficiency in eConversion mode and fast power expansion with Live Swap, Galaxy VL is the most compact galaxy in the UPS universe. Make your data center or co-location facility more sustainable today.

SE.com

### Features

- Highly efficient eConversion mode (up to 99%)
- Compact design, optimized footprint
  - Innovative Live Swap
  - Lithium-ion battery option
  - Parallel for capacity or redundancy—up to 6 UPSs
- Scalable, modular design enables N+1 internal redundancy
- Smart Power Test (SPoT) mode
  - Fault-tolerant design
- Touchscreen display with NMC
- Secure NMC Subscription License
  - Full front-service access
  - EcoStruxure connected
  - Green Premium solution
  - Startup service included

### Options

- Classic battery cabinets
  - SKRU kit
- Remote Centralized Display Box
- Bottom Entry Cabinet 65kAIC Kit
  - Seismic (with option kit)
  - Replaceable dust filters
- Backfeed protection options
  - Battery Breaker Box/Kit
- NMC embedded with ethernet (NMP) and Modbus

- Maintenance bypass cabinets

Galaxy VX

Features

Applications & Segments

- Mission-critical environments
- Large/extra-large data centers
  - Industrial applications
  - Facility infrastructure
- Cloud and Service providers
  - Colocation facilities
- Finance, semiconductor, and manufacturing environments
- Telecommunications, Healthcare
  - Highly efficient eConversion mode (up to 99%)
  - Cabinet-level scalability for capacity or redundancy
  - Dual mains input, top and bottom cable entry
- Parallel for capacity or redundancy — up to 4 UPSs
- Flywheel and Lithium-ion battery compatible
  - Internal redundancy with N+1 power cabinets
- Smart Power Test (SPoT) mode
- Touchscreen display with NMC
  - EcoStruxure connected
  - Startup service included

Options

- Battery pull box
- Network Management Card (AP9640 / AP9641 / AP9643) with Secure NMC Subscription License
  - SmartSlot cards
- Replaceable dust filters
  - Single feed kit

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For external batteries: 500 scalable to 1500 kW N+1 (400V/480V)

Sold: Worldwide

Overview

Galaxy VX is a highly efficient, modular 3-phase UPS scalable from 500 to 1500 kW in a single unit with high performance and flexible operating modes. Its scalability accommodates the changing

needs of your rapidly  
expanding business, and its exceptional performance and abundance of cost-saving features  
reduce your energy  
costs and total cost of ownership. Galaxy VX is the ideal UPS for today's large data centers,  
cloud and colocation  
facilities, as well as mission-critical applications.

SE.com

- Parallel cable kit
- Maintenance bypass cabinets
- Classical battery cabinets

Public

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Galaxy VXL

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For external batteries: 500-1250 kW (400V)

Sold: All IEC countries worldwide

SE.com

Features

Applications & Segments

- Large and extra-large  
data centers
- Colocation facilities
- Computer rooms
- Light industry & commercial  
buildings
- Cloud & Service Provider facilities
  - Semiconductor industry
  - Manufacturing critical line
    - Energy and Chemicals
  - Bank, Finance, Insurance
  - Pre-fabricated systems
- High efficiency eConversion  
mode (up to 99%)
- Compact design, optimized  
footprint only 1.2m<sup>2</sup>
  - Innovative Live Swap
- Lithium-ion battery integration
  - EcoStruxure connected
  - Scalable, modular design  
enables N+1 internal redundancy
- Reliable and fault-tolerant design
  - Sustainable solution
  - Full front access
- Unity power factor @40°C, kVA=kW

- Touchscreen display with NMC
- High short circuit level 100kA
- Secure NMC Subscription License
- Smart Power Test (SPoT) mode
  - Startup service included

#### Options

- Battery Breaker Box/Kit
- Empty Battery Cabinet

#### Overview

Galaxy VXL is a highly efficient, compact, and modular 3-phase UPS with Live Swap. With its industry-leading compact design, high-density technology, and fault-tolerant architecture, Galaxy VXL maximizes availability, operational efficiency, and critical load protection while minimizing TCO. This UPS delivers up to 97.5% efficiency in double conversion mode and up to 99% in eConversion mode, reducing the UPS Carbon emissions by a factor of two. Galaxy VXL offers proactive asset management services to give you peace of mind anytime, anywhere. Start-up service is included.

- Galaxy Lithium-ion Battery

#### Cabinets

- Air filter kit
- Parallel Communications Kit
- Seismic kit, and other options

#### Public

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#### Easy UPS 3S

For external batteries: 10-40 kVA (400V)

With and/or for internal batteries: 10-40 kVA (208V/400V)

Sold: US, Canada, Mexico, and all IEC countries worldwide, except Japan

#### Features

#### Applications & Segments

- Small data centers
- Commercial buildings & light industrial applications
  - Business-critical applications
- Healthcare, Telecommunication, Transportation, Manufacturing facilities
  - Non-IT
- Easy to install and start up; minimal footprint
  - Delivers up to 96% efficiency
- Wide operating temperature range and strong overload protection
  - Replaceable dust filters

- Strong protection against harsh environments with robust electrical specifications
  - Conformal coating
- Easy Loop Test to verify UPS performance before you connect your load
- Parallel for capacity or redundancy—up to 4 UPSs
  - Easy to manage with mimic panel
  - EcoStruxure connected
  - Long life battery string ready

#### Options

- Cold Start kit
- Parallel maintenance bypass, up to 2 units for 400V or 3 units for 208V
- Battery Breaker Box and Battery Breaker Kit
  - Empty battery cabinets
  - Standard 7Ah or 9Ah battery modules
  - NMC with Secure Subscription License
  - Start-up service

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#### Overview

Easy UPS 3S (400V) is an easy to install, use, and service 3-Phase UPS available for external batteries or with and/or for internal batteries designed for small data centers and other business critical applications.

Easy UPS 3S (208V) is an easy to install, use, and service 3-Phase UPS for internal batteries designed for small data centers, commercial buildings, non-IT, and light industrial applications.

SE.com: 400V / 208V

Public

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#### Easy UPS 3M

For external batteries: 60-200 kVA (400V) and 50-100 kVA (208V)

With internal batteries: 60-80 kVA (400V)

Sold: 208V countries of South America and Caribbean Islands, and all IEC countries worldwide, except Japan

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SE.com

#### Features

#### Applications & Segments

- Small and medium data centers and computer rooms
  - Electrical rooms
  - Business-critical applications
  - Commercial buildings
- Healthcare, Telecommunication,

## Transportation, Manufacturing facilities

- Start-up included
  - Easy deployment and compact footprint
    - Delivers up to 95.5% efficiency
  - Wide operating temperature range and strong overload protection
  - Strong protection against harsh environments with robust electrical specifications
  - Easy Loop Test to verify UPS performance before you connect your load
  - IP20 protection (extra protection with IP30, IP40, and/or IPX2 Option Kits)
    - Replaceable dust filters
  - Parallel for capacity or redundancy—up to 6 UPSs
    - Front and rear access service
  - Easy to manage with touchscreen display
  - Embedded NMC with Subscription License
    - EcoStruxure connected
- ### Options
- Parallel and unitary maintenance bypass panel
    - Modular Battery cabinet
  - Classic Battery Cabinets with batteries
    - Empty battery cabinets
  - Battery Breaker Box and Battery Breaker Kit
  - Battery string or high-capacity battery string
    - Lithium-ion battery option

### Overview

Easy UPS 3M 60-200 kVA (400V) and 50-100 kVA (208V) for external batteries, and 60-80 kVA (400V) with

internal batteries is an easy to install, connect, use, and service 3-Phase UPS for small and medium data centers,

electrical rooms, and other business-critical applications.

### Public

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### Easy UPS 3M Advanced

For external batteries: 100-250 kW (400V)

Sold: India

### Features

#### Applications & Segments

- Small and medium data centers
  - Commercial buildings
  - Light industrial applications
- Government & Public Sector Units

- Healthcare, Telecommunication, Transportation, Retail, Process Automation
- Start-up included to optimizes your system's performance, quality, and safety
- Scalable 100 kW to 250 kW for pay as you grow
  - Modular design, enabling easy serviceability
    - Easy deployment and compact footprint
      - Delivers up to 96% efficiency
- Single frame capable up to 250 kW in capacity with Internal N+1 redundancy for up to 200 kW N+1
- Wide operating temperature range and strong overload protection
  - Pluggable Draw In/Out type power module
    - kVA = kW up to 40°C
    - Replaceable dust filters
    - Front and rear access service
  - Easy to manage with 7" touchscreen display
    - EcoStruxure connected
  - Made in India enables direct sales to Government, Public Sector Units, and Infrastructure Projects

Options

- Power module
- Maintenance Bypass Panel
- Battery Breaker Box and Battery Breaker Kit

13  
Overview

Easy UPS 3M Advanced—part of the Easy UPS 3-phase range—is an easy-to-install, connect, use, service, and scale 100-250 kW (400V) 3-Phase UPS made in India that is ideal for small and medium businesses, data centers, and other mission-critical applications in India.

SE.com

- Battery Temperature Sensors
- Network Management Card (AP9640 / AP9641) with Secure NMC Subscription License

Public

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Easy UPS 3L

For external batteries: 250-600 kW (400V)

Sold: All IEC countries worldwide, except Japan and China

Applications & Segments

- Medium and large commercial buildings
  - Light industrial applications

- Computer room and regional data centers
- Healthcare, Telecommunication, Transportation, Financial, Government
- Non-IT

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#### Overview

Easy UPS 3L 250-600 kVA (400V) is an easy to configure, use, and service 3-Phase UPS that delivers high availability and predictability to medium and large commercial buildings and light industrial applications.

SE.com

#### Features

- Easy deployment and compact footprint
    - Delivers up to 96% efficiency
    - Power Module for fault-tolerant design
    - Streamlined installation and service
  - Protection against harsh environments with robust electrical specifications and ruggedizing features, including conformal coating
    - Replaceable dust filter
  - 1+1 redundant UPSs can share a common battery bank, reducing battery costs
    - IP20 (extra protection with IP31 option kit)
    - Smart Test mode optimizes site acceptance testing costs without requiring a load bank
  - Parallel up to 5 UPSs for capacity or 5+1 UPSs for redundancy
    - Supports 4+4 redundant configurations
      - Top cable entry
      - EcoStruxure connected
  - Embedded NMC with Secure NMC Subscription License
    - Start-up service included
- #### Options
- Maintenance Bypass Panel
    - Classic Battery Cabinets
    - Empty battery cabinets
  - Battery Breaker Box and Battery Breaker Kit
    - Cold Start kit
    - Lithium-ion battery option

Public

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Galaxy 3L

For external batteries: 250-600 kW (400V)

Sold: China

Features

Applications & Segments

- Medium and large data centers, and colocation facilities
  - Commercial and light industrial applications
  - Edge applications and computer rooms
- Telecommunication, Healthcare, Government Transportation, Manufacturing, Finance
  - Easy deployment and compact footprint
  - Delivers up to 96% efficiency
  - Fault-tolerant design
- Protection against harsh environments with robust electrical specifications and ruggedizing features
- 1+1 redundant UPSs can share a common battery bank, reducing battery costs
  - Top cable entry
  - Replaceable dust filter
- Embedded Network Management Card
- IP20 (extra protection with IP31 option kit)
- Smart Test mode optimizes site acceptance testing costs without requiring a load bank
- Parallel up to 5 UPSs for capacity or 5+1 UPSs for redundancy
  - Supports 4+4 redundant configurations
    - 7-inch display
    - EcoStruxure connected
    - Start-up included

Options

- Maintenance Bypass Panel
- Battery Breaker Box and Battery Breaker Kit
  - Classic Battery Cabinets
  - Empty battery cabinets
    - Cold Start kit

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Overview

Galaxy 3L 250-600 kVA (400V) is an easy to configure, use, and service 3-Phase UPS that delivers high availability and predictability to medium and large data centers, commercial buildings, and light industrial applications in China.

SE.com

- Bottom entry Cabinet
- Lithium-ion battery option

Public

16

Easy UPS 3-Phase Modular

For external batteries: 50-250 kW (400V)

Sold: All IEC countries worldwide, except Japan and China

16

Overview

Easy UPS 3-Phase Modular 50-250 kW (400V) delivers robust power protection and availability in a capital-expenditure-friendly package. It is easy to select, quote, install, and maintain, with modular, redundant, scalable options and Live Swap modules in a compact footprint.

SE.com

Features

Applications & Segments

- Easy to select, configure, start up, use, and service
- Up to 96% efficiency in double conversion mode
  - Third-party verified Live Swap functionality for fast MTTR and expansion with no scheduled downtime
- Add Live Swap power modules as demand grows
- Modular design with 50 kW power module enables N+1 redundancy to increase availability
  - Scalable design: pay as you grow
- Up to 250 kW N+1 in a black one-rack design to conserve valuable real estate
  - Unity power factor @40°C
- EcoStruxure connected for peace of mind anytime, anywhere
- Parallel 4+0, increasing power capacity to 1 MW
  - Neutral Lithium-ion Function
    - Start-up service included
    - Bottom Entry Cabinet
    - Empty Battery Cabinet
  - Battery Breaker Box and Battery Breaker Kit
    - Maintenance Bypass Panel
    - Parallel Communications Kit
  - Redundant Intelligence Module
    - Lithium-ion battery option
    - Classic Battery Cabinet
- Network Management Card (AP9640 / AP9641) with Secure NMC Subscription License
  - Other options: Depth Adapter, Backfeed Kit, Wide Seismic Kit, Battery Temperature Sensor
  - Small and medium data centers

- Telecommunication
    - Transportation
    - Healthcare
  - Process Automation Options
  - Commercial buildings
    - Retail Public
- 17

Galaxy PX UPS  
100-250 kW (400V)  
Sold: China  
Features

#### Applications & Segments

- Simple to select, configure, start up, use, and service
  - Up to 96% efficiency in double conversion mode
  - Third-party verified Live Swap functionality for fast MTTR and expansion with no scheduled downtime
  - Compact footprint with 10-inch touchscreen display
- Modular design with 50 kW power module enables N+1 redundancy to increase availability
  - Parallel 4+0, increasing power capacity to 1 MW
    - Up to 250 kW N+1 in a black one-rack design to conserve valuable real estate
  - Scalable design: optimize capex, pay as you grow
    - Unity power factor @40°C
  - EcoStruxure connected for peace of mind anytime, anywhere
    - Neutral Lithium-ion Function
      - Start-up service included
- Options
  - Bottom Entry Cabinet
    - Depth Adapter
  - Neutral Disconnection Kit for 250 KW
    - Battery Temperature Sensor
    - Parallel Communications Kit
    - Lithium-ion battery option
  - 600mm wide Seismic Kit for 250 kW
    - Backfeed Kit 250 kW
  - Network Management Card
  - Redundant Intelligence Module

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Overview

Galaxy PX 100-250 kW (400V) UPS delivers robust power protection and availability in a capital-expenditure-friendly package. It is simple to select, quote, install, and maintain, with modular, redundant, scalable options, and Live Swap modules in a compact footprint.

SE.com

- Small & medium data centers
  - Telecommunication
  - Transportation
  - Healthcare
- Process Automation • Commercial buildings
  - Retail

Symmetra PX

400V: 16-500 kW with Symmetra PX 48 All-in-One, 96/160, & 250/500

208V: 10-100 kW with Symmetra PX 20, 40, & 100

480V: 100-500 kW with Symmetra PX 100 & 250/500

Sold: Worldwide

250/500

20 40 48 AIO

96/160 100

250/500

18

SE.com

Features

Applications & Segments

- Data closet
- Small, medium, and large data centers
- Line up and match NetShelter form factor
- Configurable for N+1 internal redundancy
  - Redundant intelligent modules
  - Scalable power capacity
- Modular power, battery, bypass, and intelligent control modules
- Parallel up to 4 UPSs (Symmetra PX 250/500 only)
  - Dual mains input, top or bottom feed
  - Embedded power distribution (PX20, 48)
    - EcoStruxure connected
- Network Management Card with Secure NMC Subscription Licenses
- Start-up service included

Options

- Secondary network management card (HTTP/Telnet/SNMP)

- Seismic kits (OSHPD)
- Battery breaker enclosure

#### Overview

Symmetra PX is a high performance, right-sized, modular, scalable, 3-phase UPS that offers power protection with high availability and efficiency for small, medium, and large data centers and mission-critical environments. Made up of dedicated and redundant modules, this architecture can scale power and runtime as demand grows or as higher levels of availability are required.

- Extended runtime battery frames
- Classic battery cabinets: PX100, 96/160, 250/500
- Lithium-ion battery option for Symmetra PX 250/500
- High-density zones of large data centers
  - Mission-critical environments
  - Maintenance bypass cabinets with distribution: PX40, 100, 96/160, 250/500
  - Configurable power distribution: PX20, 40, 100
  - Modular power distribution: PX48, 96/160, 100

Public

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#### Galaxy PW 2nd Gen

##### Features

##### Applications & Segments

- Petroleum Petrochemical Gas
  - Metallurgy
  - Power Plant
  - Medical
- Semiconductor
- Transportation
- Food & Beverage
  - Mining
  - Manufacturing
- Supports dual input
- Overload capacity: 125% 10 min; 150% 1 min
- Parallel up to 3+1 (4+0)
  - ISTA 2B
- Robust design for harsh

environments

- Phase rotation check
- Standard protection class: IP31
- Operating temperature: 0-40°C
  - Supports DC cold start
- Designed for easy service
- Start-up service included

Options

- AP9547 Network Management Card with Secure NMC Subscription License
  - Replaceable dust filters
- Parallel Communications Kit
  - Backfeed Kits

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10-200 kVA (400V) transformer-based UPS

Sold: Europe, Middle East & Africa, Pacific, and Greater China

Overview

Galaxy PW 2nd Gen is a 10-200 kVA (400V) transformer-based UPS for industrial applications.

The DC busbar voltage covers 220VDC and 384VDC, and uses a reliable 6-pulse or 12-pulse SCR rectifier.

SE.com

- Cable Adapter Kits for Galaxy

Pwi

- IP42 Kit (ETO)

Products

3-phase UPSs

Products

3-phase Lithium-ion Battery Cabinets

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Public

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Galaxy Lithium-ion Battery Cabinets

Features

Applications & Segments

- Data centers, colocation, computer rooms
- Edge computing, Internet DC, cloud computing
  - Computer rooms
- Light industrial and commercial buildings
  - Infrastructure and transportation
- Telecommunications and networking
  - Critical power infrastructures
  - Emergency lighting

- UP9540A fire tested compliance
- 67Ah LMO/NCM battery system
- Double your battery life vs. VRLA solutions
- Up to 70% more compact footprint frees up floor space for revenue-generating equipment
- Boost availability with 2-3x faster recharge rates than VRLA solutions
- Built-in 3-level battery management system (BMS)
  - Green Premium solution
- Aesthetic match with Galaxy V Series UPSs
  - Self feeding SMPS simplifies installation
- Fast, simple installation — cabinet ships pre-assembled, except battery modules, and rolls quickly into place
- Enhance employee protection with modular touch-safe design, breaker covers, and built-in fuse protection at the battery cell and cabinet level
  - Seismic kit
  - EcoStruxure connected
- Start-up service options available

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For Galaxy VS, VM, VL, VX, VXL; Symmetra PX 250/500; Symmetra MW; Easy UPS 3M; Easy UPS 3L/Galaxy 3L; Easy UPS 3-Phase Modular; and Galaxy PX  
Sold: Worldwide

#### Overview

A Galaxy Lithium-ion Battery Cabinet are compact, lightweight, long-lasting, and sophisticated energy storage solution for Galaxy V series and Easy 3-phase UPSs in data centers, industrial processes, and critical infrastructures.

This UL9540A-compliant battery solution reduces battery footprint and weight by up to 70%, allowing more effective use of space. Lithium-ion batteries reduce total cost of ownership, both by doubling battery life and by operating at higher temperatures, reducing cooling requirements.

SE.com

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#### Products

3-phase IT Power Distribution

Public

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Power Distribution Units (PDUs)

Features

#### Applications

- Small, medium, and large data centers
  - Colocation facilities
- Compartmental design simplifies asset access allocation
- Meets the demanding scalability needs of any data center of any size
- Factory installed and tested Square D breaker panel configured to meet the unique needs of your site
  - Easy to install and service with top and bottom cable entry
  - Low total cost of ownership
  - Seismic cabinet (OSHDP)
  - 7-inch display interface
  - EcoStruxure connected

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#### Overview

Power Distribution Units are reliable, scalable, and intelligent high-density power distribution solutions ideal for installation in the electrical rooms of data centers.

SE.com

400 & 500 kVA (480V)

Sold: US, Central America

#### Options

- Copper or aluminum transformers
  - Main input switch or breaker
    - Main output breaker
    - Advanced metering
- Wide range of 250 Amp, 400 Amp, and 600 Amp branch breaker options from Schneider Electric's PowerPact J- and L-frame breaker series

- EPO

- Cloud service providers
- Industrial applications

400 & 500 kVA

(Aluminum) and

400 kVA (Copper)

500 kVA

(Copper)

Public

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Galaxy RPP

Features

Applications

- Data centers • Colocation facilities • Cloud service providers
  - Compact footprint and easy front-access design
  - Supports installation against walls, back-to-back, or in your EcoStruxure Pod Data Center
  - Flexible configuration, with factory installed and tested Square D breaker panels configured to your site requirements
  - Meets the demanding scalability needs of any large data center
- PowerLogic Branch Circuit Power Meter monitors single or dual feed installations
- Compartmental design simplifies asset access allocation
  - Top and bottom cable entry
- Compatible with all Schneider Electric Power Distribution Units
  - 7-inch touchscreen display
  - EcoStruxure connected

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#### Overview

Galaxy RPP (Remote Power Panels) 250 and 400 Amp (120V/208V) offers highly configurable, highly modular, high-density row-level power distribution for data centers and colocation facilities.

SE.com

250 & 400 Amp (120V/208V)

Sold: US, Canada, Central America

#### Options

- L-frame or J-frame main input breakers
    - NP, NQ, or IP2X panelboard
  - QO, QOB, or EDB distribution breakers
    - Surge protection devices
  - Start-up service options available
- Configurable and Modular Power Distribution Units
- Top or bottom cable entry (60/150 kW PDU)
    - Flexible configure-to-order options
      - Factory assembled and tested
        - Scalable
        - Modbus supported
        - Integrated monitoring
          - Network enabled
        - No side access required
        - Preconfigured cord sets
  - Compatible with StruxureWare Data Center Expert
    - Branch circuit monitoring

- Power distribution modules with locking connectors (Modular)

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Features

Applications

- Small, medium, or large data centers

Overview

Modular Power Distribution Units (PDUs) mitigate the need to predict the future requirements and

configurations of your data center.

Configurable Power Distribution Units bring agility, availability, and speed of deployment to your data

center. Our factory-tested power distribution units are built to your exact specifications, support overhead or

underfloor distribution, and feature a convenient, portable rack form factor.

Options

120/208/230/400/480/600V: 72-277 kW (Modular)

208V/480V/600V: 40-150 kW (Configurable)

Sold: Worldwide; product availability varies by region

Modular Configurable

- Shielding troughs Startup service

SE.com: Configurable and Modular

Upsilon Static Transfer Switches

30-630A standard; 800-1250A on request

Sold: All IEC regions worldwide

- Industrial applications

- Data centers

- Telecommunication centers

- Infrastructure

- Simplifies installation and maintenance while minimizing space requirements

- Independent control boards, dual cooling systems, and power supplies ensure high reliability performance

- Small footprint reduces required floor space

- Text and mimic diagrams display modes of operation, system parameters, and alarms

- Allows isolation of a source for maintenance without interrupting power to the protected loads

Options

- Communication: JBus/Modbus card (supplied as standard), status information card (supplied as standard)

- Open frame version

## Overview

Upsilon Static Transfer Switches (STS) provides true redundancy and exceptional high reliability for automatic power supply transfer to a range of equipment from two independent and redundant power sources. Static Transfer Switches automatically transfer power to a stable alternate source in less than 4ms under normal operating conditions. Even under extreme conditions, such as 180 degrees out of phase, the STS will have detection and automatic transfer times that are up to 10 times faster than many other switches.

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SE.com

- PDU (36 16A circuit breakers incorporated in the H = 1900 cell, up to 100 A)
- Connection at the top of the unit

## Features

## Applications & Segments

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## Key Applications and Segments by Product

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## IT

Small data centers

Medium data centers

Large data centers

Colocation facilities

Cloud computing

Commercial facilities

Industrial facilities

Healthcare

Transportation

Telecommunications

Energy & Chemical

Metal, Minerals, and Mining

Consumer Packaged Goods

Semi Conductor

Galaxy VS

Galaxy VM

Galaxy VL

Galaxy VX

Galaxy VXL

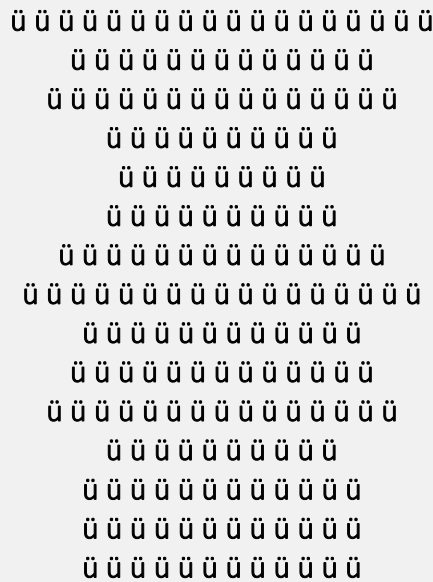
Easy UPS 3S

Easy UPS 3M

Easy UPS 3M Advanced

Easy UPS 3L

Galaxy 3L  
Easy UPS 3-Phase Modular  
Galaxy PX  
Symmetra PX  
Galaxy PW 2nd Gen  
Galaxy Lithium-ion Battery Cabinets  
Power Distribution Units (PDUs)  
Galaxy RPP  
Configurable and Modular PDUs  
Upsilon Static Transfer Switches



Key Applications and Segments by Product

To learn more about Schneider Electric 3-Phase UPS products and solutions, contact your  
Schneider

Electric representative or visit [www.se.com](http://www.se.com).

Schneider Electric  
35 rue Joseph Monier  
92500 Rueil Malmaison  
France

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specifications. • 998-19858418\_GMA-US

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General  
05/2024

EcoStruxure™ Power for Semiconductor Fabs

## Utilizing a Digital Twin for Electrical Distribution to Drive Efficient Facilities

### Reference Guide

#### EcoStruxure™ Power for

#### Semiconductor Fabs

#### General

### SECTION 3 – Digital Solutions

#### and Services

### SECTION 1 – Introduction to the

#### Semiconductor Fab Industry

### SECTION 2 – How EcoStruxure Power

#### Can Support the Semiconductor Fab

### BIBLIOGRAPHY

#### Purpose of the Document

#### Target Audience

This document is intended to address End User Engineering, Operations and Maintenance, Consultants, EPCs (Engineering, Procurement, and Construction) and Service teams and other qualified personnel.

#### Objective

To understand the challenges of designing and operating a Semiconductor Fab with an efficient and sustainable electrical distribution strategy.

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#### Table of Contents

### SECTION 1: Introduction to the

#### Semiconductor Fab

Introduces the context and the challenges of a Semiconductor Fab.

SECTION 2: How Schneider Electric  
Can Support the Semiconductor Fab  
Industry with EcoStruxure Power

Describes the solutions that EcoStruxure Power  
provides for Semiconductor Fabs, with typical  
electrical and digital architectures.

BIBLIOGRAPHY

Contains useful documents to find out more about  
capabilities.

Provides details about Green Premium.

SECTION 3: Digital Solutions and Services

Gives information about EcoStruxure Power capabilities for  
Semiconductor Fabs, sorted by value proposition:

- Transverse Lifecycle Capabilities
- Capabilities to Improve Time To Market
  - Capabilities to Increase Efficiency
  - Capabilities to Improve Resiliency
  - Capabilities to Grow Sustainability

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Semiconductor Fab Industry

Semiconductor Fab Industry Challenges

The objective

of this section is to:

- Introduce the growth, trends and  
challenges of the Semiconductor  
Fab industry
- Present the 4 pillars to meet  
the Semiconductor Fab  
challenges.

Introduction to the  
Semiconductor Fab

Industry  
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 Semiconductor Fab Industry  
 Semiconductor Fab Industry Challenges  
 Semiconductor Fab Market  
 An industry driven by the growth of new technology  
 Sources  
 Chip Shortages  
 Continue  
 17% Annual growth in chip  
 demand from 2020-2022,  
 while supply grew at only 6%  
 per year.  
 Strong Robust  
 Growth  
 +7% Robust growth till 2030.  
 Hunt for Talent  
 Intensifies  
 +77% Rise in chip-related job  
 vacancies from 2020.  
 Geopolitical Impacts  
 65% Global share of value  
 chain activities based in Asia,  
 creating high supply chain risk.  
 Focus on  
 Sustainability  
 +36% Semiconductor  
 companies reinforced ESG\*  
 practices (2021 reporting).  
 Acceleration of  
 Digital  
 Transformation  
 +52% Increased use of cloud /  
 automation in 2021.

\* ESG = Environmental, Social, and Governance

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Semiconductor Fab Industry

Semiconductor Fab Industry Challenges

Strong Robust Growth:

<https://www.mckinsey.com/industries/semiconductors/our-insights/the-semiconductor-decade-a-trillion-dollar-industry>

Hunt for Talent Intensifies:

<https://asia.nikkei.com/Business/Business-Spotlight/Chip-talent-war-Taiwan-faces-critical-staffing-shortage>

Focus on Sustainability:

<https://arstechnica.com/science/2022/04/can-semiconductor-makers-meet-surging-demands-sustainably/>

Geopolitical Impacts:

<https://www.voanews.com/a/race-for-semiconductors-influences-taiwan-conflict-/6696432.html>

Acceleration of Digital Transformation:

<https://quixy.com/blog/top-digital-transformation-statistics-trends-forecasts/#:~:text=According%20to%20Markets%20and%20Markets,by%205.1%25%20according%20to%20Gartner.>

Chip Shortages Continue:

<https://www.mynewsdesk.com/rolandberger/pressreleases/global-semiconductor-shortage-to-persist-for-several-years-beyond-2022-3151267>

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The market trends: a changing landscape	
Significant investment for expansions and modernization	
A growing focus on efficiency and sustainability	
High demand for power and water to meet semiconductor production capacity	
Cybersecurity	
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How can we reduce our operational costs?	
How can we improve power quality and minimize downtime?	
How can we reduce our carbon footprint and integrate more renewable, sustainable energy sources?	
How can we accelerate the design & build of new semiconductor fabs?	
Semiconductor Fab Industry Challenges	
Four pillars to drive efficiency, resiliency and sustainability KPIs	
The strong growth of the semiconductor industry leads to an increase in fabrication capacity.	
Creating or expanding this capacity is not without its challenges.	
Four pillars must be addressed:	
Grow	

Sustainability	
Improve	
Resiliency	
Increase	
Efficiency	
Improve Time	
to Market	
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Solutions to Address the Four Pillars	
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Example of Electrical & Digital Architectures	
The objective	
of this section is to:	
• Present the solutions to address	
the four pillars to meet the	
Semiconductor Fab industry	
challenges	
• Explain how Schneider Electric	
EcoStruxure Power can support	
this industry	
• Give an example of electrical	
and digital architectures.	
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## Example of Electrical & Digital Architectures

### Solutions to Address the Four Pillars

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Grow

Sustainability

Improve

Resiliency

Increase

Efficiency

Improve Time

to Market

### Solutions to Address the Four Pillars of Semiconductor Fabs

The four pillars can be addressed by the following solutions:

Improve Facility

Performance

Minimize

Downtime

Meet

Sustainability KPIs

Use Standardized

Architectures

Use standardized electrical  
distribution and digital tools to  
speed up the design, build  
and commissioning of new  
fabs.

Turn data into business  
intelligence and leverage a  
digital twin to provide  
actionable insights to drive  
efficiency.

Help assure optimum power  
quality and reliability while  
improving safety for your staff  
and guarding against cyber  
attacks

Engage consultancy services  
to strategize, digitize and

decarbonize.

This guide describes the solutions developed by EcoStruxure Power to address these four pillars.

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EcoStruxure Power Value Proposition  
EcoStruxure Power for Semiconductor Fabs

We are your end-to-end digital partner  
to design, build, operate and maintain  
semiconductor fabs with the utmost  
efficiency and resiliency towards a  
sustainable future.

From electrical design to  
operations and maintenance

Our collaborative environments,  
enhanced by the Electrical Distribution  
Digital Twin of your fab, enable high  
productivity operations.

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## Example of Electrical and Digital Architectures

### Typical front-end Semiconductor Fab

Energy is key, whether for processes or for utilities: specific attention must be given to the design of the electrical architecture and associated digital architecture which will enable digital solutions and services.

Front-end

Semiconductor

Fab

PROCESS 50 % UTILITIES 50 %

Ultrapure

Water (UPW)

Diffusion

Photolithography

Etching

Ion

Implantation

1

2

1

2

Subfab

Cleanroom

Others

Clean Dry Air

(CDA) and N<sub>2</sub>

Exhaust System

Cooling Water System

Physical Vapor

Deposition (PVD) /

Chemical Vapor

Deposition (CVD)

Chemical

Mechanical

Planarization

(CMP)

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Typical electrical architecture for a Semiconductor Fab	
General Example of Electrical Architecture	
UTILITY 50	
%	
Cooling Water System	
• Chilled Water	
(MV Chillers, Cooling Towers)	
• Process Cooling Water (PCW)	
• AHU, FCU, FFU, Dry Coil	
Exhaust System	
Clean Dry Ari (CDA) and N2	
Ultrapure Water (UPW)	
Others	
• Lighting	
• Wastewater	
• Air Recirculation	
• Make-Up Air Unit	
• Bulk Gases	
• Automated Materials	
Handling System (AMHS)	
• Abatement	
PROCESS 50	
%	
Critical Process	
= Power Availability	
High Energy demand	
= Efficient Energy Management	
Diffusion	
Photolithography	
Etching	
Ion Implantation	
Chemical Mechanical	
Planarization (CMP)	
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Suggested digital architecture (high-level view) for a Semiconductor Fab	
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Capabilities to Improve Your Process	
Capabilities to Improve Resiliency	
Capabilities to Grow Sustainability	
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about EcoStruxure Power	
capabilities for Semiconductor Fabs	
aligned to the industry challenges.	
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## Introduction

EcoStruxure Power provides capabilities to support the challenges of Semiconductor Fabs throughout their lifecycle

These capabilities provide standardized designs and digital architectures, and enable easy simulation, to reduce cost of design and ownership.

These capabilities use digitization to provide intelligent information to the workforce, allowing them to make smart decisions that reduce operating costs and increase efficiency.

These capabilities use digitization to reduce unplanned downtime, increase reliability, and thus reduce production waste.

These capabilities help track energy consumption and carbon emissions to meet sustainability requirements.

Design, Build, Commission

(Consultants & EPC)

Operate & Maintain

(Operators, maintenance team, service teams)

Transverse Lifecycle Capabilities

Digital Solutions that support your project from the Design, Build, Commission to Operate & Maintain phases.

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 Energy monitoring  
 and usage analysis  
 Energy performance,  
 modeling and verification  
 Capacity management  
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 Cybersecurity  
 Carbon neutrality  
 consulting services  
 Energy efficiency compliance  
 Greenhouse gas reporting  
 +  
 +  
 +  
 Grow  
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 Design, Build, Commission  
 (Consultants & EPC)  
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 (Operators, maintenance team, service teams)  
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 Asset performance  
 Power quality monitoring  
 and compliance  
 Thermal and partial

discharge monitoring  
Electrical distribution  
monitoring and alarming  
Power event analysis  
Predictive simulation  
Power quality and power  
factor correction

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Arc flash protection+

Simulate before Operate+

AC&DC electrical network  
bus design and simulation

Electrical network short  
circuit simulation

Network load flow  
and voltage drop simulation

Device coordination  
and selectivity

Arc fault protection  
and coordination

Power quality simulation  
and modeling

Renewable & microgrid energy  
storage sizing simulation

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Power system study+

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Electrical Digital Twin

Green Premium

Operator training simulation

Energy monitoring

and usage analysis

Energy performance,  
modeling and verification

Capacity management

+

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Cybersecurity

Carbon neutrality

consulting services

Energy efficiency compliance

Greenhouse gas reporting

+

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Transverse Lifecycle Capabilities

Asset performance

Power quality monitoring  
and compliance

Thermal and partial  
discharge monitoring

Electrical distribution  
monitoring and alarming

Power event analysis

Predictive simulation

Power quality and power

factor correction

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Arc flash protection+

Simulate before Operate+

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Electrical Digital Twin	
Benefits	
• Intelligent user-interface for all levels of AC and	
DC networks	
• Enables users, from the design to operate phases, to	
model, simulate, analyze and validate electrical	
power systems to predict their electrical network	
behavior	
• Takes the day-to-day system modeling and design	
tasks to a new level of speed, accuracy and ease	
Maintain a Digital Twin of your electrical distribution	
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Green Premium

Benefits

- Green Premium\* products provide detailed information on their regulatory compliance, material content, environmental impact, and circularity attributes.

Manage sustainability from design to end of life

Transverse Lifecycle Capabilities

Compliance and transparency

(compliance certificates, circularity profiles, environmental footprint, etc.)<sup>1</sup>

Circular

performance

Durability, upgradeability,  
re-manufacture, recycled  
content, recyclability

Well-being

performance

E.g. free of PVC,  
mercury, silicone,  
SVHC, lead, toxic heavy  
metal and compliant  
with California Prop 65

4

Resource

performance

Optimized energy

performance

Lower carbon

emissions

2 3

\* The Green Premium label was created to provide Schneider Electric's customers with more

sustainable products and to be transparent with environmental information.

Supporting your efforts

for a LEED certified

building

Helping you achieve

Living Building

Challenge certification

Green Premium Value Proposition

Learn more about:

- Green Premium

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Cybersecurity

Benefits

- Provides a selection of cybersecurity certified products
- Provides certified system architectures and solutions
  - Delivers lifecycle services

Help secure the digital power distribution system

Transverse Lifecycle Capabilities

Learn more about:

- Cybersecurity

Certified products developed according  
to IEC 62443 functional requirements  
with Secure Development Lifecycle  
processes.

Consulting services from design,  
implementation, operations and  
maintenance to tailor your security  
solutions to your strategy and budget.

Lifecycle services

Certified secure system architecture  
according to IEC 62443-3-3 with  
documented processes and solutions  
for a secure system. Cybersecurity  
system configuration software for  
consistent security policy deployment.

Certified products Certified systems & solutions  
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Simulate before Operate  
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Renewable & Microgrid energy  
storage sizing simulation

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+ Power system study+  
Grow  
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AC and DC Electrical Network Bus Design and Simulation	
Primary Department	
• Design	
• Construction	
Benefits	
• Single solution/environment	
- Unified AC & DC solution from HV to LV	
- One unique platform and one database	
• Efficient profile management	
- User-defined loading and generation profiles	
- External data profile based on field measurements	
• Scalability	
- Load growth study for future planning	
• Event simulations within the calculation period	
Optimize bus design allocation and simulation	
ETAP Electrical Network Model	
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Electrical Network Short Circuit Simulation	
Primary Department	
• Design	
• Construction	
Benefits	
• Expedite design studies with a wide range of	
calculation scenarios, including advanced fault	
analysis	
- IEC & ANSI duty calculation for balanced and unbalanced	
faults	
- Simultaneous fault at selected nodes	
- Inclusive 3-Phase and 1-Phase fault analysis	
- Pre-Fault system loading consideration	
Design and simulate unbalanced short circuits	
Electrical Network Short Circuit Simulation in ETAP	
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Network Load Flow and Voltage Drop Simulation	
Primary Department	
• Design	
• Construction	
Benefits	
• Simulation of bus voltages, branch power factors, currents, system losses, power generation versus loading	
• Use of ETAP Electrical Digital Twin model with powerful calculation engines and user-friendly interface	
• Simulation using multiple loading and generation conditions	
Perform power flow analysis and voltage drop calculations	
Network Load Flow and Voltage Drop Simulation in ETAP	
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Device Coordination and Selectivity	
Primary Department	

• Design	
• Construction	
Benefits	
• Verified and validated libraries	
• Graphically adjustable device settings	
• Detailed device settings reporting	
• Continuous synchronization with one-line and integrated equipment database	
Automatically detect and evaluate the system protection and coordination/selectivity	
Device Coordination and Selectivity in ETAP	
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Arc Fault Protection and Coordination	
Primary Department	
• Design	
• Construction	
Benefits	
• Evaluate, verify, and confirm the operation and selectivity of the protective devices for various types of faults for any location directly from the single-line diagram	
• Animation displayed on the single-line diagram	
• 3-phase / 1-phase sequence of operation	
Perform sequence of operation for arc fault and bolted fault	
Arc Fault Protection and Coordination in ETAP	
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Power Quality Simulation and Modeling

Primary Department

- Design

- Construction

Benefits

- Simulate harmonic current and voltage sources:

- To identify potential harmonic problems

- (report of harmonic voltage and current distortion limit violations)

- To identify the need for a harmonics filter

- Simulate and analyze the size of the harmonics filter  
your system will need to optimize performance and  
reduce nuisance trips

Evaluate and validate distortion due to harmonics

Power Quality Simulation and Modeling in ETAP

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#### Renewable and Microgrid Energy Storage Sizing Simulation

##### Primary Department

- Design

- Construction

##### Benefits

- Build renewable energy models combined with full spectrum power system analysis calculations for:

- Accurate simulation

- Predictive analysis

- Equipment sizing

- Field verification of wind, solar farms and other DERs

- Enable designers and engineers to conceptualize the collector systems, determine wind penetration and perform grid interconnection studies

##### Design and optimize the microgrid system

#### Microgrid Energy Storage Sizing Simulation in ETAP

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##### Power System Study

##### Primary Department

- Design
- Construction
- Facilities Electrical Department

Benefits

- Partner with a global team of experts, engaged with industry standards committees, to develop common safety standards and practices.
- Create a standardized approach to Power System Studies to support multisite deployments with consistent results

Work with engineering experts to provide Power System Studies

Study  
(Analyze)

Assess Design

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Green Premium

Operator training simulation

Energy monitoring  
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Energy performance,  
modeling and verification

Capacity management

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Operator Training Simulation  
Primary Department  
• Facility Operations & Maintenance

## Benefits

- Practice operation within a simulated but highly realistic environment to enhance safety and operational efficiency
- Track and review trainee actions to analyze and challenge them

Train new employees and build confidence on new systems

+

Capabilities to Increase Efficiency

Principle of Operator Training Simulation Application

Learn more about:

- Operator Training Simulation ( IEC / NEMA )

Operator Training Simulation

Reference Architecture

General Operator Training Simulation Reference Architecture

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Energy Monitoring and Usage Analysis

Primary Department

- Facility Operations & Maintenance

Benefits

- Bring awareness to utility consumption
- Turn data into easy-to-interpret graphical dashboards and reports to raise awareness amongst key stakeholders
- Identify “quick-win” opportunities for energy savings
- By comparing and visualizing energy usage and cost for different utilities over different time periods
- By identifying and prioritizing which areas lend themselves

to a high energy-saving return on investment  
Determine where to focus energy conservation initiatives  
Capabilities to Increase Efficiency  
Energy Usage Analysis Dashboards in EcoStruxure Power Operation  
Learn more about:  
• Energy Monitoring ( IEC / NEMA )  
Energy Monitoring and Usage Analysis  
Reference Architecture  
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Primary Department  
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Benefits  
• Provide energy usage information based on  
equipment and processes  
• Compare model versus actual consumption  
• Compare pre-retrofit versus post-retrofit energy  
consumption to track improved performance and  
savings as a result of energy conservation initiatives  
Analyze the energy performance of a plant against a model baseline  
Capabilities to Increase Efficiency  
Energy Performance, Modeling and Verification Output in  
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Energy Performance, Modeling and Verification  
Reference Architecture  
Learn more about:

• Energy Performance ( IEC / NEMA )	
• Energy Modeling and verification ( IEC / NEMA )	
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Capacity Management	
Primary Department	
• Facility Operations & Maintenance	
Benefits	
• Monitor electrical network capacity	
• Track and review capacity efficiency	
• Minimize downtime by tracking the capacity of	
transformers, circuit breakers, UPSs, generators, etc.	
Monitor the capacity of electrical distribution	
Capabilities to Increase Efficiency	
Breaker Capacity Single-line Diagram in EcoStruxure Power Operation	
Capacity Management	
Reference Architecture	
Learn more about:	
• Capacity Management ( IEC / NEMA )	
General Capacity Management Reference Architecture	
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Predictive Simulation	
Help employees make better decisions	
Primary Department	
• Facility Engineering	
• Design Engineering	
Benefits	
• Reduce safety risks by practicing emergencies and high-risk situations	
• Enhance operational efficiency by running “what-if” scenarios	
• Provide faster analysis response to incidents	
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Simulate Before Operate	
Empower operators with predictive outcomes	
Primary Department	
• Facility Operations & Maintenance	
Benefits	
• Provide operators with a list of potential side effects, prior to executing a command	
• Empower employees to feel more confident when operating their facilities by providing real time guidance	
• Reduce human error that could lead to outages or safety concerns	
Capabilities to Improve Resiliency	
+	
Simulate Before Operate	
Reference Architecture	
Principle of Simulate before Operate Application	
Learn more about:	
• Simulate Before Operate ( IEC / NEMA )	
General Simulate Before Operate Reference Architecture	
Reference Guide	
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Electrical Distribution Monitoring and Alarming	
Monitor and control electrical network	
Primary Department	
• Facility Operations & Maintenance	
Benefits	
• Show real-time status of the power distribution	
• Customized single-line diagram	
• 24/7 power monitoring and alarm notification	
Capabilities to Improve Resiliency	
Electrical Distribution Monitoring and Alarming Single-line Diagram in EcoStruxure	
Power Operation	
Electrical Distribution Monitoring and Alarming	
Reference Architecture	
Learn more about:	
• Electrical distribution monitoring and alarming	
(IEC / NEMA)	
• Power Source and Load Control ( IEC / NEMA )	
General Electrical Distribution Monitoring and Alarming Reference Architecture	
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Power Events Analysis	
Analyze the root causes of electrical events	
Primary Department	
• Facility Operations & Maintenance	
Benefits	
• Automatically classifies and describes any electrical	

events

- Uses system intelligence to determine root cause and location of events
- Shows context and sequence of events using the timeline analysis interface

Capabilities to Improve Resiliency

Event and Alarm Status view in EcoStruxure Power Operation

Event and Alarm Status Timeline in EcoStruxure Power Operation

Power Event Analysis

Reference Architecture

Learn more about:

- Power Event Analysis (IEC / NEMA)

General Power Events Analysis Reference Architecture

Reference Guide

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Capabilities to Grow Sustainability

Asset Performance

Benefit from a strategic maintenance approach

Primary Department

- Facility Operations & Maintenance

Benefits

- Move from reactive or preventive to condition-based (predictive) maintenance strategies for critical assets like circuit breakers, gensets, transformers, etc.
- Provide event details and notification to the operator if a protection setting has been changed
- Receive notifications and diagnostics reports from expert service engineers with recommendations to optimize maintenance by asset or site

Capabilities to Improve Resiliency	
Asset Performance	
Reference Architecture	
Aging Diagram for Circuit Breakers in EcoStruxure Power Operation	
Gigafactory	
Learn more about:	
• Asset Performance (IEC / NEMA)	
General Asset Performance Reference Architecture	
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Capabilities to Grow Sustainability	
Power Quality Monitoring and Compliance	
Gain insights to improve power quality and comply with standards	
Primary Department	
• Facility Operations & Maintenance	
Benefits	
• Bring awareness of power quality	
• Enhance operational efficiency by making sure clean	
power is fed to sensitive process equipment	
• Help protect sensitive equipment by tracking power	
quality problems before they arise	
Capabilities to Improve Resiliency	
Power Quality and Compliance Dashboards in EcoStruxure Power Operation	
Power Quality and Compliance Report in EcoStruxure Power Operation	
Power Quality Monitoring and Compliance	
Reference Architecture	
Learn more about:	
• Power Quality Monitoring and Compliance	
(IEC / NEMA)	

General Power Quality Monitoring and Compliance Reference Architecture	
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Capabilities to Grow Sustainability	
Power Quality and Power Factor Correction	
Help protect sensitive equipment from power quality issues	
Primary Department	
• Facility Operations & Maintenance	
Benefits	
• Monitor sensitive process lines and busbars	
• Provide clean power to sensitive process equipment	
• Track Power Quality problems to help avoid	
downtime	
• Reduce financial impact of power factor on energy	
bill	
Capabilities to Improve Resiliency	
Galaxy	
VM	
Power Quality Information in EcoStruxure Power Operation	
Before and After Power Quality and Power Factor Correction Implementation	
Power Quality and Power Factor Correction	
Reference Architecture	
Learn more about:	
• Power Quality Correction (IEC / NEMA)	
• Power Factor Correction (IEC / NEMA)	
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Capabilities to Grow Sustainability	
Continuous Thermal Monitoring & Partial Discharge Monitoring	
Help prevent electrical fires and help protect employees and equipment	
Primary Department	
• Facility Operations & Maintenance	
Benefits	
• Provide early detection of internal arcing or temperature abnormalities in equipment that can cause damage	
- To help reduce the risk of equipment and electrical room damage	
- To improve service continuity	
• Enable optimized maintenance schedules by providing continuous monitoring vs calendar-based service	
Capabilities to Improve Resiliency	
Continuous Thermal Monitoring & Partial Discharge Monitoring	
Reference Architecture	
Learn more about:	
• Continuous Thermal monitoring ( IEC / NEMA )	
Continuous Thermal Monitoring in the Single-line Diagram of EcoStruxure	
Power Operation	
General Continuous Thermal Monitoring and Partial Discharge Monitoring Reference	
Architecture	
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Arc Flash Protection	
Help protect employees and equipment	
Primary Department	
• Facility Operations & Maintenance	
Benefits	
• Help prevent loss of life and reduce the risk of equipment and electrical room damage	
• Improve maintenance team awareness to help troubleshoot and identify the root cause of arc flash events	
Arc Flash in a Switchboard	
Arc Flash Alert and Location in EcoStruxure Power Operation	
Capabilities to Improve Resiliency	
Arc Flash Protection	
Reference Architecture	
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• Arc Flash Protection ( IEC / NEMA )	
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Electrical Digital Twin

Green Premium

Operator training simulation

Energy monitoring

and usage analysis

Energy performance,  
modeling and verification

Capacity management

+

+

+

+

Cybersecurity

Carbon neutrality

consulting services

Energy efficiency compliance

Greenhouse gas reporting

+

+

+

Transverse Lifecycle Capabilities

Asset performance

Power quality monitoring

and compliance

Thermal and partial

discharge monitoring

Electrical distribution

monitoring and alarming

Power event analysis

Predictive simulation

Power quality and power

factor correction

+

+

+

+

+

+

+

Arc flash protection+

Simulate before Operate+  
 AC&DC electrical network  
 bus design and simulation  
 Electrical network short  
 circuit simulation  
 Network load flow  
 and voltage drop simulation  
 Device coordination  
 and selectivity  
 Arc fault protection  
 and coordination  
 Power quality simulation  
 and modeling  
 Renewable & microgrid energy  
 storage sizing simulation  
 +  
 +  
 +  
 +  
 +  
 +  
 +  
 Power system study  
 Grow  
 Sustainability  
 Improve  
 Resiliency  
 Increase  
 Efficiency  
 Improve  
 Time to Market  
 Design, Build, Commission  
 (Consultants & EPC)  
 Operate & Maintain  
 (Operators, maintenance team, service teams)  
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Capabilities to Improve Resiliency

Carbon Neutrality Consulting Services

Track and reduce carbon emissions to demonstrate the carbon neutrality of the company

Primary Department

- Facility Operations & Maintenance
  - Sustainability Office

Benefits

- Get support from our consulting services to define your strategy for achieving carbon neutrality

Capabilities to Grow Sustainability

+ Services

Carbon neutrality

Reduce

Carbon Emissions

Produce

Renewable Energy

Purchase

Renewables/Offsets

Energy Efficiency

- Sustainable building design & operations

– HVAC Efficiency

– Lighting Efficiency

– Operational Efficiency

Behind-the-Meter

Renewables

- Solar Panels / Heating
  - Wind

- Geothermal

Purchase Renewables

- Renewable Power Purchasing Agreements (PPA)

- Renewable Energy Certificates (REC)

- Biofuels

Supporting Technologies

• Microgrid with Smart Management	
• Battery Storage	
• Fuel Cells	
Purchase Offsets	
• Carbon Credits	
– Carbon Capture	
– Tree Planting	
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Energy Efficiency Compliance	
Comply with standards related to energy management systems	
Primary Department	
• Facility Operations & Maintenance	
• Sustainability Office	
Benefits	
• Report and show facility compliance to local	
sustainability requirements	
- To benefit from tax credits	
- To gain credibility to participate in new projects	
Capabilities to Improve Sustainability	
EcoStruxure Power Operation	
Energy Star Compliance Dashboard	
EcoStruxure Resource Advisor Dashboard	
in EcoStruxure Power Operation	
Sustainable Organizations and Standards	
Energy Efficiency Compliance	
Reference Architecture	

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Greenhouse Gas Reporting	
Track and report carbon emissions	
Primary Department	
• Facility Operations & Maintenance	
• Sustainability Office	
Benefits	
• Track and report carbon emissions and waste	
(e.g., water) in one single place	
• Provide period-over-period usage comparison	
to detect a drift	
Capabilities to Improve Sustainability	
Greenhouse Gas Reporting	
Reference Architecture	
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Greenhouse Gas Reporting and Dashboard Examples in EcoStruxure Power Operation	
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Design Guide  
IEC EcoStruxure Power Design Guide  
Ref: ESXP2G001EN  
02/2024

Digital Applications for Large Buildings and Critical Facilities  
The Digital Applications Design Guide provides comprehensive details  
on the building blocks of EcoStruxure Power: the IoT applications are driven  
by a software layer to control the traditional electrical distribution  
infrastructure.

Developed to help engineering consultants and designers, this guide  
is an invaluable resource for specifying, designing and prescribing  
EcoStruxure Power architectures capable of performing one or more  
of the business-driven applications described within.

NEMA EcoStruxure Power Design Guide  
Ref: 0100DB1802  
01/2024

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2024/05/28

ESXP2RG002EN  
PEP method for assessing  
3-Phase UPS sustainability  
[se.com](http://se.com)  
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UPS carbon footprint  
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UPS carbon  
calculation tool

4

- Common errors to avoid when comparing UPSs
  - Steps for accurate UPS comparisons
  - What is a PEP and how to read it
- Product specific rules (PSR) for 3-phase UPS
  - Carbon profile of a typical 3-phase UPS

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Introduction

Life is On | Schneider Electric

Introduction

As discussed in White Paper 64, Why Data Centers Must Prioritize Environmental Sustainability: Four Key Drivers, companies are seeking ways of decreasing their data center's environmental footprint and of their company in general. These needs apply to all data center sizes, from the largest multi-megawatt purpose-built data center to a single-rack micro data center in a branch office. Most vendors recognize these needs and therefore promote their product's sustainability as a means to help their customers attain their sustainability goals.

As one of the leading companies in demonstrating sustainability<sup>1</sup>, Schneider Electric believes that customers care about three key topics when it comes to sustainable products:

- 1 Schneider Electric recognized in Corporate Knights' Global 100 for the 12th year in a row
- 2 Sustainability data that is free and available to all customers and validates product claims, including documentation like environmental product disclosures and product end-of-life treatments.
- 3 Performance characteristics that improve a product's sustainability, including lower impact materials, energy efficiency, durability, repairability, and take-back.

1

Compliance with applicable regulations, particularly those related to hazardous substances.

Includes mandatory compliance to hazardous substance regulations such as the European directive for Restriction of Hazardous Substances (RoHS); European Regulation

for Registration, Evaluation (REACH); European directive for Waste from Electrical and Electronic Equipment (WEEE); China RoHS; and California Proposition 65.

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Environmental declarations

An environmental product declaration (EPD) summarizes the environmental life cycle data of a product or service and is normally valid for five years. These documents help specifiers make

Uninterruptible Power Supply (UPS) decisions based on environmental impacts like carbon footprint and water use, making it easier to compare UPSs of the same category.

The International Organization for Standardization (ISO) publishes the standards that underly EPDs, in particular ISO 14025. EPDs must be based on life cycle assessment (LCA) data or life cycle inventory analysis (LCI) data, which are governed by the ISO 14040 standard. For more information on ISO standards, see Schneider Electric

White Paper 70. Note that ISO 14040 is generic and applies to all types of products and services.

The following sections explain how to read an EPD, explain three key concepts of a 3-phase UPS PSR, and describe the typical carbon profile of a 3-phase UPS.

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Environmental declarations

Program operators like the P.E.P. Association administer programs in compliance with ISO 14025 so that EPDs report the same type of information. They develop, approve, and publish product category rules (PCR) and product-specific rules (PSR) for Type III environmental declarations. All EPDs must be independently verified by internal or external experts and provide information need to track Scope 1, 2, and 3 emissions.

For this e-guide, the PCR related to a UPS covers electrical, electronic, and HVAC-R products and defines how vendors should perform the LCA. When the PCR isn't detailed enough to develop EPDs for specific products, program operators develop PSRs.

P.E.P. Association 11/17, rue de l'Amiral Hamelin - 75016 Paris  
Non-profit association (Law of 1901) – SIRET No.: 789 180 320 00010  
PEP ecopassport® PROGRAM  
PCR

Product Category Rules for Electrical,  
Electronic and HVAC-R Products

PCR-ed4-EN-2021 09 06

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Secretariat, which may be contacted at: [contact@pep-ecopassport.org](mailto:contact@pep-ecopassport.org)

Reporting environmental data for a UPS

2 This applies to business-to-business products only.

3 See Appendix of White Paper 67, Guide to Environmental Sustainability Metrics for Data Centers, for information on Scope 1, 2, and 3.

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What is a PEP and how to read it

PEP stands for Product Environmental Profile. The PEP Ecopassport association defines which mandatory information a PEP must provide. While the templates change from vendor to vendor, the key information needed for a UPS comparison is usually presented in the following order:

6 Verification information

5 Environmental impacts

4 Additional environmental information

3 Constituent materials

2 The “function” or “functional unit”

1 The “reference product” or “representative product”

All values in the PEP are expressed in scientific notation using a decimal value with an exponential (E) of 10. In this example:

$1.97E06 = 1.97 \times 10E6 = 1.97 \times 1,000,000 = 1,970,000$

PEP contains the CO<sub>2</sub> emissions data of the product

PEP Extract of a 3-phase UPS: Galaxy VX

The 'Contribution to climate change' contains the CO<sub>2</sub> Emissions of the product expressed in kg CO<sub>2</sub> equivalent.

Description of the different

Life Stages of the product

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The PSRs define rules for specific products within the larger product category. Due to their unique function, such as multiple operating modes,

UPSs are one of those products that require their own product specific rules.

There are 3 key concepts in the UPS PSR that play a significant role in determining the life cycle carbon footprint of a UPS.

1. Reference Service Life (RSL)

The RSL is the length of time the UPS is expected to remain in service. According to

section 3.5.5.1 of the PSR, a 3-phase UPS over 10 kW has a service life of 15 years. This means that the life cycle assessment accounts for 15 years of UPS emissions.

For example, if the electricity use emissions for the UPS is 100,000 kg CO<sub>2</sub>

e per year,

its lifetime electricity emissions would be 100,000 kg CO<sub>2</sub>

e x 15 years or

1,500,000 kg CO<sub>2</sub>

e.

## 2. Typical load profile

A load profile is meant to ensure that all manufacturers use the same assumptions to calculate electricity use. A load profile includes % load, length of time a UPS operates during its lifetime, and UPS operating mode.

For 3-phase UPSs greater than 10 kW, the electricity use is based on operating at:

- 25% load for 25% of the UPS life (3.75 years)
- 50% load for 50% of the UPS life (7.5 years)
- 75% load for 25% of the UPS life (3.75 years)
- 100% load at 0% of the UPS life (0 years)

Product specific rules (PSR) for 3-phase UPS

Reference Service Life (RSL) of a UPS

Typical load profile of a UPS

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## 3. Energy efficiency calculation

The percent load and operating mode are important because they determine the UPS's efficiency at a specific load percentage. If a UPS has two operating modes, it will have two different efficiency values that characterize each mode.

However, according to UPS PSR section 3.5.5.3, the electricity use calculation must be based on the UPS's operating mode with the worst case weighted efficiency; which in most cases is double conversion.

The weighted efficiency for a 3-phase UPS (>10 kW) is calculated according to the formula:

Weighted efficiency = 25% x Eff<sub>25%</sub> + 50% x Eff<sub>50%</sub> + 25% x Eff<sub>75%</sub> + 0% x Eff<sub>100%</sub>

Product specific rules (PSR) for 3-phase UPS (continued)

Efficiency figures at different load percentages for two operating modes (example: Galaxy VX 1250 kW)

Weighted efficiency in double conversion

= 25% x 95.6% + 50% x 96% + 25% x 95.7% + 0% x 95.2% = 95.8%

Weighted efficiency in eConversion

= 25% x 97.9% + 50% x 98.8% + 25% x 98.9% + 0% x 99% = 98.6%

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Because a UPS operates continuously over its lifetime, the largest contribution to its carbon emissions comes from the "use" stage.

While there are significant differences among UPS models in terms of efficiency and the associated electrical losses, electricity consumption is by

far the largest contributor of CO<sub>2</sub>

e life cycle emissions. Here is an example of how each stage of the lifecycle contributes to

the CO<sub>2</sub>e emissions  
of a 3-phase UPS taken from the Galaxy VX PEP. The use stage emissions represent about 93% of the UPS's carbon footprint.

#### Carbon profile of a typical 3-phase UPS

Manufacturing

6.2%

Distribution

0.1%

Installation

0.0%

Use

93.3%

End of life

0.4%

Galaxy VX UPS 1250 - CO<sub>2</sub>e emissions per life stage  
Manufacturing Distribution Installation Use End of life

Use

93.3%

Breakdown of total carbon footprint for a 3-phase UPS (example: Galaxy VX).

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#### UPS carbon footprint comparisons

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- A sustainability comparison makes sense only after developing a list of UPS models that meet your functional requirements.
- In the case of a UPS, requirements may include kW capacity, physical footprint, efficiency, modularity, etc. Once you have a list of UPSs, then you can quantitatively compare their environmental characteristics.
  - The most effective way to do this is to compare their PEPs.
- A comprehensive UPS carbon footprint comparison should consider all five of its life cycle stages. This section first explains common errors to avoid when comparing UPSs and then provides step by step guidance on comparing each of the five life cycle stages.
- We use two UPSs to demonstrate the comparison. A key theme in this section is the concept of comparing “apples to apples.”

#### UPS carbon footprint comparisons

##### Common errors to avoid when comparing products

While the ISO standards provide the basis for LCAs and PEPs, they don't eliminate vendor mistakes or ensure valid comparisons. Therefore, end users must be vigilant when comparing PEPs for two or more UPSs, especially if they're from different vendors. This section covers the major errors people make when comparing the carbon footprint of two or more UPS.

Life is On | Schneider Electric

An emission factor is the ratio of greenhouse gas emitted for every kWh of electricity a

utility generates. The emission factor is multiplied by the energy (kWh) the UPS uses in its lifetime to arrive at the use stage emissions from electrical losses.

Because a UPS operates continuously over its lifetime, the largest contribution to its carbon emissions comes from the use stage. Even a small difference in emission factors has a major impact on a comparison.

This is why you can't compare UPSs with different grid emission factors. An example of this frequent error is illustrated here. As shown in the table below, it's quite possible for a PEP of an inefficient UPS (e.g., UPS X at 94%) to show lower total emissions than a more efficient UPS (e.g., Galaxy VX at 95.8%) with an (erroneously calculated) 980,000 kg CO<sub>2</sub>

e vs. 2,000,000 kg  
CO<sub>2</sub>

e. In reality, only the second and the third line can be used for an apples-to-apples comparison, which shows that UPS X emissions are much higher than Galaxy VX.

How different grid emission factors impact CO<sub>2</sub>  
e emissions declaration.

Example:

1250kW UPS

Efficiency % Grid Emissions Factor  
(kgCO<sub>2</sub>/kWh)

Grid geography CO<sub>2</sub> emissions  
declared in PeP (Use phase) in kgCO<sub>2</sub>

UPS X 94% 0,2 FR 980 000

94% 0,41 EU-27 2 000 000

Galaxy VX 95,8% 0,41 EU-27 1 400 000

2

22kW UPS

Comparing "use stage" carbon emissions based on different utility grid emission factorsError  
#1

When the emission factors are set equal (0.41 kg CO<sub>2</sub>  
e/kWh), the total CO<sub>2</sub>

e footprint for the low-efficiency UPS is 1.4 times higher than  
the high-efficiency UPS.

This example was calculated assuming an overall emission factor for the 27 European  
countries (0.41 kg CO<sub>2</sub>  
e/kWh)

compared to that of France (0.2 kg CO<sub>2</sub>  
e/kWh) 6

6 This is an older (and higher) value than today's EU-27 and France values. The program operator, P.E.P. Association, tries to keep this value consistent over the years to avoid publishing PEP documents based on different emission factors.

## Life is On | Schneider Electric

Example of CO2 footprint comparison between UPS with different emission factors. Because PEPs use codes that can be difficult to understand, an easier way to assess the use stage emissions between two or more UPSs is to compare their efficiencies with the same grid emission factor. The 3-phase UPS Efficiency Comparison Calculator simplifies this task.

0

500,000

1,000,000

1,500,000

2,000,000

2,500,000

Manufacturing Distribution Installation Use End of life

UPS CO2e footprint

UPS X - 94% eff using French EF (0.2 kg CO2e/kWh

UPS X - 94% eff using European EF (0.4 kg CO2e/kWh

GVX - 96% eff using European EF (0.4 kg CO2e/kWh

Incorrect comparison

Correct comparison since both UPS  
use the same emission factor (EF)

2

2

2

Common errors to avoid when comparing products

## Life is On | Schneider Electric

If a UPS has two operating modes, it will have two efficiency curves characterizing each mode. An example of this is illustrated using the

Three Phase

UPS Efficiency Comparison Calculator.

Example of UPS efficiency curves for two different operating modes.

- UPS with two operating modes will have two efficiency curves
- Generally cannot compare values from different operating modes
- If operator uses high-efficiency for one UPS but double conversion with another, values cannot be compared

Comparing “use stage” carbon emissions with different operating modesError #2

## Life is On | Schneider Electric

Common errors to avoid when comparing products

Declaring a winning attribute

that is within the margin of errorError #7

Granting recycling credit without

evidence of recycling programError #6

Assuming a PEP includes

expected componentsError #5

Comparing UPS PEPs with

different PSR and PCR versionsError #4

Comparing UPSs with  
different capacitiesError #3

Life is On | Schneider Electric

Calculate the weighted UPS efficiency for the operating mode that will actually be used (e.g., double conversion or high-efficiency mode). The typical operating mode is double conversion. Do this for each UPS you're comparing using the formula provided below:

This step requires:

- The total energy consumption (kWh) – sum of all reference test loads from Step 2
- The grid emission factor (kg CO<sub>2</sub> e/kWh) – Ideally, the emission factor is the same as that of the electric grid supplying the UPS.

This final step sums the emissions from all five life cycle stages (i.e., manufacturing, distribution, installation, use, and end of life) using the UPS PEP document. If the UPSs have different rated capacities, then you should compare the total carbon footprint using the 'K- factor' described above, or use the data from the nearest UPS rating provided in the PEP. This will allow you to see which UPS has the lowest total carbon footprint.

This step requires the following for each UPS you're comparing:

- The efficiencies from Step 1
- The grid emission factor (kg CO<sub>2</sub> e/kWh) – Ideally, the emission factor is the same as that of the electric grid supplying the UPS.
- The rated capacity of the UPS (kW)
- The UPS reference service life (RSL) (15 years)

Step 1: Calculate the weighted efficiency.

Step 3: Calculate UPS electricity CO<sub>2</sub> emissions. Step 4: Add CO<sub>2</sub> emissions from the other life stages.

Step 2: Calculate UPS electricity consumption.

Four steps for accurate UPS comparisons

This section describes the steps required to accurately compare two or more UPSs.

UPS life cycle electricity  
emissions (kg CO<sub>2</sub>  
e)

Weighted  
efficiency

Total energy  
consumption kWh

Emission factor  
(kg CO<sub>2</sub>  
e/kWh)

=

=

x

$$25\% \times \text{Eff}25\% + 50\% \times \text{Eff}50\% + 25\% \times \text{Eff}75\% + 0\% \times \text{Eff}100\%$$

Life is On | Schneider Electric

### UPS carbon calculation tool

This section describes the excel worksheet that facilitates UPS carbon footprint comparisons using the four steps described in the previous section. We describe each input that the worksheet uses to calculate the total life cycle carbon footprint for the UPS models you're comparing.

All input cells are highlighted in yellow.

Main input cells:

#### UPS carbon footprint comparison tool

In Step 1, the set of inputs describe the efficiency of the UPSs you're comparing. The UPS model and operating mode inputs are used only to label the efficiency data. The efficiency data should have at least one decimal of precision. Note, you must choose the operating mode that will actually be used at the site (typically double conversion).

With the data provided by the Three Phase UPS Efficiency Comparison Calculator, you can enter the efficiencies in the yellow cells for most Schneider Electric UPSs.

Table used to calculate weighted UPS efficiency:

In Step 2 & 3, with the data entered thus far, the tool calculates the electricity consumption (kWh) and electricity-based emissions (kg CO<sub>2</sub>e)

in the green rows.

Table used to calculate the electricity consumption (kWh) and electricity-based emissions (kg CO<sub>2</sub>e):

Per Step 4, the last part of the worksheet sums the emissions from the remaining life cycle stages (i.e., manufacturing, distribution, installation, and end of life) using the values in the UPS PEP document. The worksheet also calculates the emissions per unit kW of rated UPS capacity in case the UPSs have different rated capacities.

Table used to calculate the total UPS life cycle carbon emissions (kg CO<sub>2</sub>e):

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Conclusion

Life is On | Schneider Electric

As more companies and consumers seek to reduce their environmental footprint, vendors are responding with claims of environmentally sustainable UPSs. Assessing the environmental

sustainability of a UPS is complex and claims are difficult to ascertain without knowing the underlying assumptions and standards upon which they are made. By understanding the calculations behind the sustainability claims of the UPS you are considering, you can confidently choose a UPS that is better for your operations and the planet.

This e-guide defined and covered five life cycle stages that encompass a UPS's environmental sustainability performance. We provided explanations for how to calculate the electricity-based UPS emissions. Finally, we offered guidance for how to accurately assess the sustainability of similar UPSs and a tool to help with UPS comparisons.

#### Conclusion

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998-23218491\_GMA

To learn more about addressing your UPS's environmental sustainability, visit:

[se.com](https://se.com)

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General

05/2024

EcoStruxure™ Power for EV Battery Manufacturing Plants  
Utilizing a Digital Twin for Electrical Distribution to Drive Efficient Facilities

#### Reference Guide

EcoStruxure™ Power for  
EV Battery Manufacturing Plants  
General

SECTION 3 – Digital Solutions  
and Services

SECTION 1 – Introduction to the  
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SECTION 2 – How SE Can Support  
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Purpose of the Document

Target Audience

This document is intended to address End User  
Engineering, Operations and Maintenance,  
Consultants, EPCs (Engineering, Procurement, and  
Construction) and Service teams and other qualified  
personnel.

## Objective

To understand the challenges of designing and operating an EV battery manufacturing plant with an efficient and sustainable electrical distribution strategy.

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#### SECTION 1: Introduction to the Electrical Vehicle Battery Manufacturing Plants

Introduces the context and the challenges of EV battery manufacturing plants.

#### SECTION 2: How Schneider Electric Can Support Electrical Vehicle Battery Manufacturing Plants

Describes the solutions that Schneider Electric and, more specifically EcoStruxure Power provides for EV battery manufacturing plants, with typical electrical and digital architecture.

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Contains useful documents to find out more about capabilities.

Provides details about Green Premium.

#### SECTION 3: Digital Solutions and Services

Gives information about EcoStruxure Power capabilities for EV battery Manufacturing plants, sorted by value proposition:

- Transverse Lifecycle Capabilities
- Capabilities to Improve Time To Market
- Capabilities to Improve Your Process
  - Capabilities to Improve Quality
  - Capabilities to Grow Sustainability

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EV Battery Market  
EV Battery Manufacturing Plant Challenges  
The objective  
of this section is to:

- Introduce the growth, trends and  
challenges of the EV battery  
market
- Present the 4 pillars to meet  
the EV battery manufacturing  
plant challenges.

Introduction to the  
Electrical Vehicle Battery  
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EV Battery Manufacturing Plant Challenges  
EV Battery Market  
An industry driven by the electrical vehicle market  
8 EV models  
Launched by Nissan by  
the end of 2023. Goal is to

be on pace to sell 1M hybrid  
or electric vehicles per  
year globally.

15-25% sales of  
hybrid & EV

For BMW by 2025.

20 EV models

Launched by Audi by the end  
of 2025.

27 B\$ investment

By General Motors in EV  
infrastructure through 2025  
with the aim of releasing 30  
EV vehicles onto the market  
within the same timeframe

1 M hybrid &  
electrical vehicles

On the road pledged by Volvo  
by end of 2025. Expectation of  
50% of global sales from EVs.

10 EV models

Introduced by Mercedes by  
the end of 2023.

Ban of diesel- and  
gas-powered cars

In the UK expected to go into  
effect by 2030.

Sources <https://www.caranddriver.com/news/g35562831/ev-plans-automakers-timeline/>  
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EV Battery Manufacturing Plant Challenges  
EV Battery Market

The market trends: a changing landscape  
Significant investment in Greenfield and expansions

A growing focus on efficiency and sustainability  
 High demand for energy and power to meet battery  
 production capacity  
 Cybersecurity  
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 EV Battery Manufacturing Plant Challenges  
 How can we minimize  
 downtime to increase  
 yield rates and improve  
 production quality?  
 How can we be best-in-  
 class for CO2 emissions  
 per kWh?  
 How to improve the overall  
 energy efficiency of  
 the plant and process?  
 How can we accelerate  
 the design & build  
 of new EV battery plants?  
 EV Battery Manufacturing Plant Challenges  
 Four pillars to drive efficiency, reliability and sustainability KPIs  
 The strong growth of the EV market leads to an increasing need for battery manufacturing  
 plants.  
 Creating or expanding EV battery manufacturing plants is not without its challenges.  
 Four pillars must be addressed:  
 Grow  
 Sustainability  
 Improve  
 Quality  
 Improve  
 Your Process  
 Improve Time  
 to Market

How can we reduce the cost of finished battery cells?	
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Solutions to Address the Four Pillars	
Schneider Electric Value Propositions	
Example of Electrical and Digital Architecture	
The objective of this section is to:	
• Present the solutions to address the four pillars to meet the EV battery manufacturing plant challenges	
• Explain how Schneider Electric EcoStruxure™ Power can support this industry	
• Give an example of electrical and digital architectures.	
How Schneider Electric Can Support Electrical Vehicle Battery Manufacturing Plants	
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Grow

Sustainability

Improve

Quality

Improve

Your Process

Improve Time

to Market

Solutions to Address the Four Pillars of EV Battery Manufacturing Plants

The four pillars can be addressed by the following solutions:

Increase Production

Efficiency

Reduce Production

Hazards

Track Sustainability

KPIs

Use Standardized

Architectures

Use standardized electrical  
distribution and IT

infrastructures in order to  
speed up the “design, build  
and commission” phase  
of new plants.

Digitize and modernize  
your operations and turn  
data into useful business  
intelligence to empower  
your workforce, understand  
the profitability of your  
production assets and make  
smart business decisions  
for your entire ecosystem.

Reduce downtimes and  
manage end-to-end quality  
to reduce production scrap.

Utilize control tower and IoT  
platforms to collect analytics  
on processes, settings and

maintenance.  
Monitor sustainability criteria  
to accelerate environmental  
transition and be compliant  
with sustainability standards  
and customer expectations.

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Schneider Electric Value Propositions  
At company level

Through its entire organization, Schneider Electric has developed value propositions to  
address the four pillars  
for the different parts of EV battery manufacturing plants:

Infrastructure  
/ Facility  
Manufacturing  
Process  
Manufacturing  
Machine  
Design and  
Modeling  
Digital  
Automation & IOT  
Framework  
EcoStruxure  
Machine  
Architecture  
Energy Efficiency  
Process  
Efficiency  
Machine  
Performance

& Flexibility	
Power Availability	
Predictive Quality	
Machine Tracking	
& Monitoring	
Green House Gas	
and Energy	
Compliance	
Energy	
Optimization	
Sustainable	
Sourcing	
Grow	
Sustainability	
Improve	
Quality	
Improve	
Your Process	
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Schneider Electric Value Propositions	
At EcoStruxure Power level	
This guide focuses more specifically on value propositions provided by EcoStruxure Power:	
Manufacturing	
Process	
Manufacturing	
Machine	
Digital	

Automation & IOT  
Framework  
EcoStruxure  
Machine  
Architecture  
Process  
Efficiency  
Machine  
Performance  
& Flexibility  
Predictive Quality  
Machine Tracking  
& Monitoring  
Energy  
Optimization  
Sustainable  
Sourcing  
Grow  
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Transverse Lifecycle Capabilities  
(Cybersecurity, Green Premium, Electrical Digital Twin)  
Infrastructure  
/ Facility  
Design and  
Modeling Energy Efficiency Power Availability  
Green House Gas  
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At EcoStruxure Power level

EcoStruxure Power helps deliver an  
end-to-end digital solution for efficient,  
reliable and sustainable EV Battery  
Plants.

From electrode production to  
cell finishing,

From electrical design to  
operations and maintenance,

Our collaborative environments,  
enhanced by the Electrical Distribution  
Digital Twin of your Plant, enable high  
productivity operations.

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Example of Electrical and Digital Architecture

Typical EV battery manufacturing plant

Energy is key, whether for processes or for utilities: specific attention must be given to the  
design of the electrical

architecture and associated digital architecture which will enable digital solutions and  
services.

EV battery

manufacturing plant

PROCESS

Energy consumption 60 % UTILITY

Energy consumption 40 %

Cell assembly

Utilities – Clean and dry  
room

Ageing/Formation

Utilities Infrastructure

3% Mixing

Coating and drying

Vacuum drying

Calendering

Slitting

23 %

2%

2% 2% 2%

26 %

37 %

3%

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Example of Electrical and Digital Architecture

Typical electrical architecture for an EV battery manufacturing plant

Example of Electrical Architecture

General Example of Electrical Architecture

Expensive Process

= Power Availability

High Energy demand

= Efficient Energy Management

ELECTRODE PRODUCTION

- Mixing

- Coating & Drying

- Calendering

- Slitting

- Vacuum Drying

CELL ASSEMBLY

- Electrode shaping
  - Stacking
- Electric contacting
  - Case insertion
  - Case closure
- CELL FINISHING
  - Electrolyte filling
  - Pre-charging
  - Filling hole closure
- Ageing & formation
- INFRASTRUCTURE
  - Emergency Loads
- IT and Control Room
- Lightings and other
- UTILITIES
  - Dry Room MV Chillers and Dryers
- Clean Room MV Chillers
  - Cooling Water
  - Waste Treatment
    - Inert gas (N2)
- PROCESS UTILITY

60

%

40

%

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Example of Electrical and Digital Architectures

Suggested digital architecture (high-level view) for an EV battery manufacturing plant

Example of Digital Architecture (High-Level View)

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Grow

Sustainability

Improve

Quality

Improve

Your Process

Improve

Time to Market

Introduction

EcoStruxure Power provides capabilities to support the challenges of EV battery  
manufacturing plant throughout  
the plant lifecycle:

These capabilities provide  
standardized designs and  
digital architectures, and  
enable easy simulation,  
to reduce cost of design  
and ownership.

These capabilities use  
digitization to provide  
intelligent information to the  
workforce, allowing them to  
make smart decisions that  
reduce operating costs and

increase efficiency.	
These capabilities use digitization to reduce unplanned downtime, increase reliability, and thus reduce production waste.	
These capabilities help track energy consumption and carbon emissions to meet sustainability requirements.	
Design, Build, Commission	
(Consultants & EPC)	
Operate & Maintain	
(Operators, maintenance team, service teams)	
Transverse Lifecycle Capabilities	
Digital Solutions that support your project from the Design, Build, Commission to Operate & Maintain phases.	
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Electrical Digital Twin	
Green Premium	
Operator training simulation	
Energy monitoring and usage analysis	
Energy performance, modeling and verification	
Capacity management	

+  
 +  
 +  
 +  
 Cybersecurity  
 Carbon neutrality  
 consulting services  
 Energy efficiency compliance  
 Greenhouse gas reporting  
 +  
 +  
 +  
 Grow  
 Sustainability  
 Improve  
 Quality  
 Improve  
 Your Process  
 Improve  
 Time to Market  
 Design, Build, Commission  
 (Consultants & EPC)  
 Operate & Maintain  
 (Operators, maintenance team, service teams)  
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 AC&DC electrical network  
 bus design and simulation  
 Electrical network short  
 circuit simulation  
 Network load flow  
 and voltage drop simulation  
 Device coordination  
 and selectivity  
 Arc fault protection  
 and coordination  
 Power quality simulation  
 and modeling  
 Renewable & microgrid energy  
 storage sizing simulation  
 +  
 +  
 +  
 +  
 +

+  
 +  
 Asset performance  
 Power quality monitoring  
 and compliance  
 Continuous thermal  
 monitoring  
 Electrical distribution  
 monitoring and alarming  
 Power event analysis  
 Predictive simulation  
 Power quality and power  
 factor correction  
 +  
 +  
 +  
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 +  
 +  
 Arc flash protection+  
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 Operator training simulation

Energy monitoring  
 and usage analysis  
 Energy performance,  
 modeling and verification  
 Capacity management  
 +  
 +  
 +  
 +  
 Cybersecurity  
 Carbon neutrality  
 consulting services  
 Energy efficiency compliance  
 Greenhouse gas reporting  
 +  
 +  
 +  
 Grow  
 Sustainability  
 Improve  
 Quality  
 Improve  
 Your Process  
 Improve  
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 Electrical network short  
 circuit simulation  
 Network load flow  
 and voltage drop simulation  
 Device coordination  
 and selectivity  
 Arc fault protection  
 and coordination  
 Power quality simulation  
 and modeling  
 Renewable & microgrid energy  
 storage sizing simulation

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Asset performance  
Power quality monitoring  
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Continuous thermal  
monitoring  
Electrical distribution  
monitoring and alarming  
Power event analysis  
Predictive simulation  
Power quality and power  
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Arc flash protection+  
Simulate before Operate+  
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Electrical Digital Twin	
Maintain a Digital Twin of your electrical distribution	
Benefits	
• Intelligent user-interface for all levels of AC and DC networks	
• Enables users, from the design to operate phases, to model, simulate, analyze and validate electrical power systems to predict their electrical network behavior	
• Takes the day-to-day system modeling and design tasks to a new level of speed, accuracy and ease	
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Green Premium	
Manage sustainability from design to end of life	
Benefits	
• Green Premium* products provide detailed information on their regulatory compliance, material content, environmental impact, and circularity attributes.	
Transverse Lifecycle Capabilities	
Compliance and transparency	
(compliance certificates, circularity profiles, environmental footprint, etc.) <sup>1</sup>	
Circular	
performance	
Durability, upgradeability,	

re-manufacture, recycled  
content, recyclability

Well-being

performance

E.g. free of PVC,  
mercury, silicone,  
SVHC, lead, toxic heavy  
metal and compliant  
with California Prop 65

4

Resource

performance

Optimized energy

performance

Lower carbon  
emissions

2 3

\* The Green Premium label was created to provide Schneider Electric's customers with  
more

sustainable products and to be transparent with environmental information.

Supporting your efforts

for a LEED certified

building

Helping you achieve

Living Building

Challenge certification

Green Premium Value Proposition

Learn more about:

- Green Premium

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Cybersecurity

Help secure the digital power distribution system

Benefits

- Provides a selection of cybersecurity certified products
- Provides certified system architectures and solutions
  - Delivers lifecycle services

Transverse Lifecycle Capabilities

Learn more about:

- Cybersecurity

Certified products developed according  
to IEC 62443 functional requirements  
with Secure Development Lifecycle  
processes.

Consulting services from design,  
implementation, operations and  
maintenance to tailor your security  
solutions to your strategy and budget.

Lifecycle services

Certified secure system architecture  
according to IEC 62443-3-3 with  
documented processes and solutions  
for a secure system. Cybersecurity  
system configuration software for  
consistent security policy deployment.

Certified products Certified systems & solutions

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 Energy performance,  
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 Capacity management  
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 Carbon neutrality  
 consulting services  
 Energy efficiency compliance  
 Greenhouse gas reporting  
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Arc fault protection  
and coordination  
Power quality simulation  
and modeling  
Renewable & microgrid energy  
storage sizing simulation

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AC and DC Electrical Network Bus Design and Simulation	
Optimize bus design allocation and simulation	
Primary Department	
• Design	
• Construction	
Benefits	
• Single solution/environment	
- Unified AC & DC solution from HV to LV	
- One unique platform and one database	
• Efficient profile management	
- User-defined loading and generation profiles	
- External data profile based on field measurements	
• Scalability	
- Load growth study for future planning	
• Event simulations within the calculation period	
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ETAP Electrical Network Model	
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Electrical Network Short Circuit Simulation  
Design and simulate unbalanced short circuits  
Primary Department

- Design
- Construction

Benefits

- Expedite design studies with a wide range of calculation scenarios, including advanced fault analysis
- IEC & ANSI duty calculation for balanced and unbalanced faults
  - Simultaneous fault at selected nodes
  - Inclusive 3-Phase and 1-Phase fault analysis
  - Pre-Fault system loading consideration

Electrical Network Short Circuit Simulation in ETAP  
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Network Load Flow and Voltage Drop Simulation

Perform power flow analysis and voltage drop calculations

Primary Department

- Design
- Construction

Benefits

- Simulation of bus voltages, branch power factors, currents, system losses, power generation versus loading
- Use of ETAP Electrical Digital Twin model with

powerful calculation engines and user-friendly interface

- Simulation using multiple loading and generation conditions Network Load Flow and Voltage Drop Simulation in ETAP

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Device Coordination and Selectivity

Automatically detect and evaluate the system protection and coordination/selectivity

Primary Department

- Design
- Construction

Benefits

- Verified and validated libraries
- Graphically adjustable device settings
- Detailed device settings reporting
- Continuous synchronization with one-line and integrated equipment database

Device Coordination and Selectivity in ETAP

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Arc Fault Protection and Coordination	
Perform sequence of operation for arc fault and bolted fault	
Primary Department	
• Design	
• Construction	
Benefits	
• Evaluate, verify, and confirm the operation and selectivity of the protective devices for various types	
of faults for any location directly from the single-line diagram	
• Animation displayed on the single-line diagram	
• 3-phase / 1-phase sequence of operation	
Arc Fault Protection and Coordination in ETAP	
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Power Quality Simulation and Modeling	
Evaluate and validate distortion due to harmonics	

Primary Department	
• Design	
• Construction	
Benefits	
• Simulate harmonic current and voltage sources:	
- To identify potential harmonic problems	
(report of harmonic voltage and current distortion limit	
violations)	
- To identify the need for a harmonics filter	
• Simulate and analyze the size of the harmonics	
filter your system will need to optimize	
performance and reduce nuisance trips	
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Renewable and Microgrid Energy Storage Sizing Simulation	
Design and optimize the microgrid system	
Primary Department	
• Design	
• Construction	
Benefits	
• Build renewable energy models combined with full	
spectrum power system analysis calculations for:	
- Accurate simulation	
- Predictive analysis	
- Equipment sizing	
- Field verification of wind, solar farms and other DERs	

- Enable designers and engineers to conceptualize the collector systems, determine wind penetration and perform grid interconnection studies

Microgrid Energy Storage Sizing Simulation in ETAP

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Green Premium

Operator training simulation

Energy monitoring and usage analysis

Energy performance, modeling and verification

Capacity management

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Cybersecurity

Carbon neutrality consulting services

Energy efficiency compliance

Greenhouse gas reporting

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Renewable & microgrid energy  
storage sizing simulation  
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Capabilities to Grow Sustainability

Operator Training Simulation

Train new employees and build confidence on new systems

Primary Department

- Facility Operations & Maintenance

Benefits

- Practice operation within a simulated but highly realistic environment to enhance safety and operational efficiency
- Track and review trainee actions to analyze and challenge them

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Capabilities to Improve Your Process

Learn more about:

- Operator Training Simulation ( IEC / NEMA )

Principle of Operator Training Simulation Application	
Operator Training Simulation	
Reference Architecture	
General Operator Training Simulation Reference Architecture	
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Energy Monitoring and Usage Analysis	
Determine where to focus energy conservation initiatives	
Primary Department	
• Facility Operations & Maintenance	
Benefits	
• Bring awareness to utility consumption	
- Turn data into easy-to-interpret graphical dashboards and	
reports to raise awareness amongst key stakeholders	
• Identify “quick-win” opportunities for energy savings	
- By comparing and visualizing energy usage and cost for	
different utilities over different time periods	
- By identifying and prioritizing which areas lend themselves	
to a high energy-saving return on investment	
Capabilities to Improve Your Process	
Energy Usage Analysis Dashboards in EcoStruxure Power Operation	
Learn more about:	
• Energy Monitoring ( IEC / NEMA )	
Energy Monitoring and Usage Analysis	
Reference Architecture	
General Energy Monitoring and Usage Analysis Reference Architecture	
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Energy Performance, Modeling and Verification	
Analyze the energy performance of a plant against a model baseline	
Primary Department	
• Facility Operations & Maintenance	
Benefits	
• Provide energy usage information based on	
equipment and processes	
• Compare model versus actual consumption	
• Compare pre-retrofit versus post-retrofit energy	
consumption to track improved performance and	
savings as a result of energy conservation initiatives	
Capabilities to Improve Your Process	
Energy Performance, Modeling and Verification Output in	
EcoStruxure Power Operation	
Learn more about:	
• Energy Performance ( IEC / NEMA )	
• Energy Modeling and verification ( IEC / NEMA )	
Energy Performance, Modeling and Verification	
Reference Architecture	
General Energy Performance Modeling and Verification Reference Architecture	
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Capacity Management	
Monitor the capacity of electrical distribution	
Primary Department	
• Facility Operations & Maintenance	
Benefits	
• Monitor electrical network capacity	
• Track and review capacity efficiency	
• Minimize downtime by tracking the capacity of	
transformers, circuit breakers, UPSs, generators,	
etc.	
Capabilities to Improve Your Process	
Breaker Capacity Single-line Diagram in EcoStruxure Power Operation	
Learn more about:	
• Capacity Management ( IEC / NEMA )	
Capacity Management	
Reference Architecture	
General Capacity Management Reference Architecture	
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Power quality simulation

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Renewable & microgrid energy

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Electrical Digital Twin

Green Premium

Operator training simulation

Energy monitoring

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Energy performance,  
modeling and verification

Capacity management

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Cybersecurity

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Energy efficiency compliance

Greenhouse gas reporting

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Predictive Simulation	
Help employees make better decisions	
Primary Department	
• Facility Engineering	
• Design Engineering	
Benefits	
• Reduce safety risks by practicing emergencies and high-risk situations	
• Enhance operational efficiency by running “what-if” scenarios	
• Provide faster analysis response to incidents	
Capabilities to Improve Quality	
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Principle of Predictive Simulation Application	
Predictive Simulation	
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Simulate Before Operate	
Empower operators with predictive outcomes	
Primary Department	

• Facility Operations & Maintenance Benefits	
• Provide operators with a list of potential side effects, prior to executing a command	
• Empower employees to feel more confident when operating their facilities by providing real time guidance	
• Reduce human error that could lead to outages or safety concerns	
Capabilities to Improve Quality	
Learn more about:	
• Simulate Before Operate ( IEC / NEMA )	
Principle of Simulate before Operate Application	
Simulate Before Operate	
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Electrical Distribution Monitoring and Alarming	
Monitor and control electrical network	
Primary Department	
• Facility Operations & Maintenance Benefits	
• Show real-time status of the power distribution	
• Customized single-line diagram	
• 24/7 power monitoring and alarm notification	
Capabilities to Improve Quality	
Electrical Distribution Monitoring and Alarming Single-line Diagram in EcoStruxure	

Power Operation	
Learn more about:	
• Electrical distribution monitoring and alarming (IEC / NEMA)	
• Power Source and Load Control ( IEC / NEMA )	
Electrical Distribution Monitoring and Alarming	
Reference Architecture	
General Electrical Distribution Monitoring and Alarming Reference Architecture	
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Power Event Analysis	
Analyze the root causes of electrical events	
Primary Department	
• Facility Operations & Maintenance	
Benefits	
• Automatically classifies and describes any electrical events	
• Uses system intelligence to determine root cause and location of events	
• Shows context and sequence of events using the timeline analysis interface	
Event and Alarm Status view in EcoStruxure Power Operation	
Event and Alarm Status Timeline in EcoStruxure Power Operation	
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Learn more about:	
• Power Event Analysis (IEC / NEMA)	
Power Event Analysis	
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Asset Performance

Benefit from a strategic maintenance approach

Primary Department

- Facility Operations & Maintenance

Benefits

- Move from reactive or preventive to condition-based (predictive) maintenance strategies for critical assets like circuit breakers, gensets, transformers, etc.
- Provide event details and notification to the operator if a protection setting has been changed
- Receive notifications and diagnostics reports from expert service engineers with recommendations to optimize maintenance by asset or site

Capabilities to Improve Quality

Aging Diagram for Circuit Breakers in EcoStruxure Power Operation

Gigafactory

Learn more about:

- Asset Performance (IEC / NEMA)

Asset Performance

Reference Architecture

General Asset Performance Reference Architecture

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Power Quality Monitoring and Compliance	
Gain insights to improve power quality and comply with standards	
Primary Department	
• Facility Operations & Maintenance	
Benefits	
• Bring awareness of power quality	
• Enhance operational efficiency by making sure clean power is fed to sensitive process equipment	
• Help protect sensitive equipment by tracking power quality problems before they arise	
Capabilities to Improve Quality	
Power Quality and Compliance Dashboards in EcoStruxure Power Operation	
Power Quality and Compliance Report in EcoStruxure Power Operation	
Learn more about:	
• Power Quality Monitoring and Compliance (IEC / NEMA)	
Power Quality Monitoring and Compliance	
Reference Architecture	
General Power Quality Monitoring and Compliance Reference Architecture	
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#### Power Quality and Power Factor Correction

#### Help protect sensitive equipment from power quality issues

##### Primary Department

- Facility Operations & Maintenance

##### Benefits

- Monitor sensitive process lines and busbars
- Provide clean power to sensitive process equipment
  - Track Power Quality problems to help avoid downtime
- Reduce financial impact of power factor on energy bill

##### Capabilities to Improve Quality

##### Galaxy

##### VM

#### Power Quality Information in EcoStruxure Power Operation

#### Before and After Power Quality and Power Factor Correction ImplementationLearn more about:

- Power Quality Correction (IEC / NEMA)
- Power Factor Correction (IEC / NEMA)

#### Power Quality and Power Factor Correction

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#### General Power Quality and Power Factor Correction Reference Architecture

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##### Transverse Lifecycle Capabilities

Capabilities to Improve Time to Market  
 Capabilities to Improve Your Process  
 Capabilities to Grow Sustainability  
 Continuous Thermal Monitoring  
 Help prevent electrical fires and help protect equipment  
 Primary Department  
 • Facility Operations & Maintenance  
 Benefits  
 • Bring early detection of temperature abnormalities  
 • Help reduce the risk of equipment and electrical  
 room damage and improve service continuity  
 • Enable cost effective maintenance  
 Continuous Thermal Monitoring in the Single-line Diagram of EcoStruxure  
 Power Operation  
 Continuous Thermal Monitoring  
 Reference Architecture  
 Capabilities to Improve Quality  
 Learn more about:  
 • Continuous Thermal monitoring ( IEC / NEMA )  
 General Continuous Thermal Monitoring Reference Architecture  
 Reference Guide  
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 Capabilities to Improve Time to Market  
 Capabilities to Improve Your Process  
 Capabilities to Grow Sustainability  
 Arc Flash Protection  
 Help protect employees and equipment  
 Primary Department  
 • Facility Operations & Maintenance  
 Benefits  
 • Help prevent loss of life and reduce the risk of

equipment and electrical room damage

- Improve maintenance team awareness to help troubleshoot and identify the root cause of arc flash events

Capabilities to Improve Quality

Learn more about:

- Arc Flash Protection ( IEC / NEMA )

Arc Flash in a Switchboard

Arc Flash Alert and Location in EcoStruxure Power Operation

Arc Flash Protection

Reference Architecture

General Arc Flash Protection Reference Architecture

Reference Guide

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Overview of Digital Solutions and Services

Electrical Digital Twin

Green Premium

Operator training simulation

Energy monitoring and usage analysis

Energy performance, modeling and verification

Capacity management

+

+

+

+

Cybersecurity

Carbon neutrality  
 consulting services  
 Energy efficiency compliance  
 Greenhouse gas reporting  
 +  
 +  
 +  
 Grow  
 Sustainability  
 Improve  
 Quality  
 Improve  
 Your Process  
 Improve  
 Time to Market  
 Design, Build, Commission  
 (Consultants & EPC)  
 Operate & Maintain  
 (Operators, maintenance team, service teams)  
 Transverse Lifecycle Capabilities  
 AC&DC electrical network  
 bus design and simulation  
 Electrical network short  
 circuit simulation  
 Network load flow  
 and voltage drop simulation  
 Device coordination  
 and selectivity  
 Arc fault protection  
 and coordination  
 Power quality simulation  
 and modeling  
 Renewable & microgrid energy  
 storage sizing simulation  
 +  
 +  
 +  
 +  
 +  
 +  
 +  
 Asset performance  
 Power quality monitoring  
 and compliance

Continuous thermal  
monitoring  
Electrical distribution  
monitoring and alarming  
Power event analysis  
Predictive simulation  
Power quality and power  
factor correction

+

+

+

+

+

+

+

Arc flash protection+  
Simulate before Operate+  
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Capabilities to Improve Quality

Carbon Neutrality Consulting Services

Primary Department

- Facility Operations & Maintenance
  - Sustainability Office

Benefits

- Get support from our consulting services to define your strategy for  
achieving carbon neutrality

Track and reduce carbon emissions to demonstrate the carbon neutrality of the company

Capabilities to Grow Sustainability

- + Services
- Carbon neutrality
- Reduce
- Carbon Emissions
- Produce
- Renewable Energy
- Purchase
- Renewables/Offsets
- Energy Efficiency
- Sustainable building design & operations
  - HVAC Efficiency
  - Lighting Efficiency
  - Operational Efficiency
- Behind-the-Meter
- Renewables
- Solar Panels / Heating
  - Wind
  - Geothermal
- Purchase Renewables
- Renewable Power Purchasing Agreements (PPA)
- Renewable Energy Certificates (REC)
  - Biofuels
- Supporting Technologies
- Microgrid with Smart Management
  - Battery Storage
  - Fuel Cells
- Purchase Offsets
- Carbon Credits
- Carbon Capture
- Tree Planting
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Capabilities to Improve Your Process	
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Energy Efficiency Compliance	
Primary Department	
• Facility Operations & Maintenance	
• Sustainability Office	
Benefits	
• Report and show facility compliance to local sustainability requirements	
- To benefit from tax credits	
- To gain credibility to participate in new projects	
Comply with standards related to energy management systems	
Capabilities to Grow Sustainability	
EcoStruxure Power Operation	
Energy Star Compliance Dashboard	
EcoStruxure Resource Advisor Dashboard	
in EcoStruxure Power Operation	
Sustainable Organizations and Standards	
Learn more about:	
• Energy Efficiency Compliance ( IEC / NEMA )	
Energy Efficiency Compliance	
Reference Architecture	
General Energy Efficiency Compliance Reference Architecture	
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Capabilities to Improve Time to Market

Capabilities to Improve Your Process

Capabilities to Improve Quality

Greenhouse Gas Reporting

Primary Department

- Facility Operations & Maintenance

- Sustainability Office

Benefits

- Track and report carbon emissions and waste (e.g., water) in one single place
- Provide period-over-period usage comparison to detect a drift

Track and report carbon emissions

Greenhouse Gas Reporting and Dashboard Examples in EcoStruxure Power Operation

Capabilities to Grow Sustainability

Greenhouse Gas Reporting

Reference Architecture

Learn more about:

- Greenhouse Gas Reporting ( IEC / NEMA )

General Greenhouse Gas Reporting Reference Architecture

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Design Guide

IEC EcoStruxure Power Design Guide

Ref: ESXP2G001EN

02/2024

Digital Applications for Large Buildings and Critical Facilities

The Digital Applications Design Guide provides comprehensive details on the building blocks of EcoStruxure Power: the IoT applications are driven by a software layer to control the traditional electrical distribution infrastructure.

Developed to help engineering consultants and designers, this guide is an invaluable resource for specifying, designing and prescribing EcoStruxure Power architectures capable of performing one or more of the business-driven applications described within.

NEMA EcoStruxure Power Design Guide

Ref: 0100DB1802

01/2024

<https://www.se.com/ww/en/download/document/ESXP2G001EN/>

<https://www.se.com/us/en/download/document/0100DB1802/>

Web version

PDF version

Web version

[https://go.schneider-electric.com/WW\\_202004\\_Digital-Applications-for-Large-Buildings-and-Critical-Facilities\\_EA-LP.html](https://go.schneider-electric.com/WW_202004_Digital-Applications-for-Large-Buildings-and-Critical-Facilities_EA-LP.html)

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<https://www.se.com/ww/en/work/campaign/innovation/power-digital-applications-design-guide.jsp>

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General

2024/05/28

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Modicon

Standard

Register

Number

Absolute Starting Register Address,  
(Hexa-decimal)

Absolute

Starting

Register

Address,

(Decimal)

Bit Data Point

Length

#

register

s

Data Type

Multiply

Reading

By:

Divide Reading

By: Valid Response

Status Data

40002 0x0001 1 UPS Status 1

0 UPS operation mode - Battery BOOLEAN 1=UPS operation mode - Battery

1 Battery is below minimum acceptable runtime BOOLEAN 1=Battery is below minimum

acceptable runtime  
 2 Bypass BOOLEAN 1=UPS is in Bypass  
 3 UPS operation mode - Battery Test BOOLEAN 1=UPS operation mode - Battery Test  
 4 Reserved BOOLEAN  
 5 High Efficiency Mode disable by system BOOLEAN 1=High Efficiency Mode (ECO, EConversion) disable by system  
 6 Reserved BOOLEAN  
 7 Reserved BOOLEAN  
 8 Reserved BOOLEAN  
 9 Battery fault BOOLEAN 1=Battery fault  
 10 Reserved BOOLEAN  
 11 Reserved BOOLEAN  
 12 Reserved BOOLEAN  
 13 Informational alarm present BOOLEAN 1=Informational alarm present  
 14 Warning alarm present BOOLEAN 1=Warning alarm present  
 15 Critical alarm present BOOLEAN 1=Critical alarm present  
 40003 0x0002 2 Alarm Register 1  
 0  
 Lost local network management interface - to - UPS  
 communication BOOLEAN  
 1=Lost local network management interface - to - UPS communication  
 1 Display communication is lost BOOLEAN 1=Main Controller is unable to communicate with  
 the display  
 2 Parallel communication incorrect on PBUS cable 1 BOOLEAN 1=Parallel communication  
 incorrect on PBUS cable 1  
 3 Parallel communication incorrect on PBUS cable 2 BOOLEAN 1=Parallel communication  
 incorrect on PBUS cable 2  
 4 MegaTie activation alarm BOOLEAN 1=MegaTie activation is present  
 5 Reserved BOOLEAN  
 6 Reserved BOOLEAN  
 7 Reserved BOOLEAN  
 8 Reserved BOOLEAN  
 9 Reserved BOOLEAN  
 10 Reserved BOOLEAN  
 11 Reserved BOOLEAN  
 12 Communication cable termination fault BOOLEAN 1=Communication cable termination  
 fault  
 13 General parallel system incorrect BOOLEAN 1=General parallel system incorrect  
 14 Lost parallel redundancy BOOLEAN 1=Lost parallel redundancy  
 15 Reserved BOOLEAN  
 40004 0x0003 3 Alarm Register  
 0 Reserved BOOLEAN  
 1 UPS operation mode - Requested Static Bypass BOOLEAN 1=UPS operation mode -  
 Requested Static Bypass

2 UPS operation mode - Forced Static Bypass  
Boolean 1=UPS operation mode - Forced Static Bypass

Modbus Register Map: Galaxy VX (3:3 250kW-1500kW)

Scale

Notes:

1. 16-bit registers are transmitted MSB first (i.e. big-endian).
2. INT32 and UINT32 are most-significant word in n+0, least significant word in n+1 (i.e. big-endian).
3. Function codes 3 and 4 are supported
4. Modbus serial RTU and Modbus over TCP is supported.
5. Signed numbers are twos-compliment
6. Status bits are atomic within a single Modbus register. User should not look for consistency across multiple registers, only within a single register.
7. For ASCII strings less than the maximum length, the unused characters are filled with nulls.
8. Single-register reads of reserved or undefined registers will return an error. Block reads which begin with a valid register will not return an error but will return zeros for undefined registers.
9. Strings are two characters per register, first character in high-order byte, second character in low-order byte. Printable ASCII only.
10. Bit #0 is least significant bit.
11. Data Type column: "INT16"=signed 16-bit integer, "UINT16" = unsigned 16-bit integer, "INT32" = signed 32-bit integer, "UINT32" = unsigned 32-bit integer, "ENUM" is a UINT16 value which maps to a defined list of states, "ASCII" = the printable ASCII subset from 0x20 - 0x7E. BOOLEAN= a single bit, 0 or 1.
12. "Absolute Starting Register Address" = 0 (the column heading used in this table) is equivalent to "Register 40001" in Modicon terminology, which is address zero when transmitted over the wire.

For detailed modbus configuration settings, please refer to the Display or AP9635 User's Guide.

990-5915E

May/ 2024

Modicon

Standard

Register

Number

Absolute Starting Register Address,  
(Hexa-decimal)

Absolute

Starting

Register

Address,

(Decimal)

Bit	Data Point	Length	#	register	s	Data Type	Multiply	Reading	By:	Divide Reading	By: Valid Response	Scale
3	UPS operation mode - Maintenance Bypass	BOOLEAN	1	UPS operation mode - Maintenance Bypass								
4	Reserved	BOOLEAN										
5	UPS operation mode - Off	BOOLEAN	1	UPS operation mode - Off								
6	UPS operation mode - Initialize	BOOLEAN	1	UPS operation mode - Initialize								
7	Reserved	BOOLEAN										
8	Reserved	BOOLEAN										
9	Reserved	BOOLEAN										
10	Reserved	BOOLEAN										
11	Input phase sequence incorrect	BOOLEAN	1	Input phase sequence incorrect								
12	Input frequency out of range	BOOLEAN	1	Input frequency out of range								
13	Input voltage out of range	BOOLEAN	1	Input voltage is out of range								
14	Selftest - Failed	BOOLEAN	1	Self test has failed								
15	Power cabinet mixed operation mode (Battery and Normal)	BOOLEAN										
1	Power Cabinet in mixed operation mode (Battery and Normal)											
40005	0x0004	4	Alarm Register 1									
0	Reserved	BOOLEAN										
1	Reserved	BOOLEAN										
2	Reserved	BOOLEAN										
3	Bypass frequency out of range	BOOLEAN	1	Bypass frequency out of range								
4	Bypass phase sequence incorrect	BOOLEAN	1	Bypass phase sequence incorrect								
5	Reserved	BOOLEAN										
6	Reserved	BOOLEAN										
7	Reserved	BOOLEAN										
8	Overload on UPS	BOOLEAN	1	Overload on UPS								
9	Overload on Static bypass switch	BOOLEAN	1	Overload on Static bypass switch								
10	Ambient temperature out of range	BOOLEAN	1	Ambient temperature out of range								
11	EPO Switch Activated	BOOLEAN	1	EPO Switch activated								
12	Ground fault detected	BOOLEAN	1	Ground fault detected								
13	Reserved	BOOLEAN										

14 Bypass voltage out of range BOOLEAN 1=Bypass voltage is out of range

15 High Efficiency mode is disable due to bypass UTHD BOOLEAN 1=Bypass UTHD is out of range for High Efficiency Mode

40006 0x0005 5 Alarm Register 1

0 System locked in bypass operation BOOLEAN 1=System locked in bypass operation

1 Batteries are discharging BOOLEAN 1=Batteries are discharging

2 Reserved BOOLEAN

3 Reserved BOOLEAN

4 Continuous Overload on UPS BOOLEAN 1=Overload on UPS present. Load below Continuous Overload Threshold.

5 Charge power is reduced BOOLEAN 1=Charge power is reduced

6 Reserved BOOLEAN

7 Reserved BOOLEAN

8 Reserved BOOLEAN

9 Distributed Energy Reserved Mode activated BOOLEAN 1= Distributed Energy Reserved mode activated

10 Reserved BOOLEAN

11 Reserved BOOLEAN

12 Battery condition is weak BOOLEAN 1=Battery condition is weak

13 Battery condition is poor BOOLEAN 1=Battery condition is poor

14 Reserved BOOLEAN

15 Battery capacity is below minimum acceptable level BOOLEAN 1=Battery capacity is below minimum acceptable level

40007 0x0006 6 Alarm Register 1

0 Reserved BOOLEAN

1 Reserved BOOLEAN

2 Reserved BOOLEAN

3 Reserved BOOLEAN

4 Reserved BOOLEAN

5 Reserved BOOLEAN

6 Reserved BOOLEAN

7 Reserved BOOLEAN

8 Reserved BOOLEAN

9 Reserved BOOLEAN

10 Reserved BOOLEAN

11 Reserved BOOLEAN

12 Reserved BOOLEAN

13 Reserved BOOLEAN

14 Reserved BOOLEAN

15 Power cabinet redundancy lost BOOLEAN 1=Power cabinet redundancy lost

40008 0x0007 7 Alarm Register 1

0 Reserved BOOLEAN

1 Bypass transfert inhibited by relay input activated BOOLEAN 1= transfert to bypass is inhibited by input relay activated

2 DC ground fault BOOLEAN 1= DC ground fault is present

Modicon

Standard

Register

Number

Absolute Starting Register Address,  
(Hexa-decimal)

Absolute

Starting

Register

Address,

(Decimal)

Bit Data Point

Length

#

register

s

Data Type

Multiply

Reading

By:

Divide Reading

By: Valid Response

Scale

3 Ambient temperature high BOOLEAN 1 = Ambient temperature is high

4 Overload on UPS due to high ambient temperature BOOLEAN 1 = Overload on UPS due to  
high ambient temperature

5 Output frequency out of range BOOLEAN 1=Output frequency out of range

6 Output voltage out of range BOOLEAN 1=Output voltage is out of range

7 Reserved BOOLEAN

8 Reserved BOOLEAN

9 Reserved BOOLEAN

10 Reserved BOOLEAN

11 Reserved BOOLEAN

12 Overload on installation BOOLEAN 1=Overload on installation

13 Reserved BOOLEAN

14 Reserved BOOLEAN

15 Reserved BOOLEAN

40009 0x0008 8 Alarm Register 1

0 Reserved BOOLEAN

1 Reserved BOOLEAN

2 Reserved BOOLEAN

3 Reserved BOOLEAN

4 Reserved BOOLEAN

5 Reserved BOOLEAN  
 6 Reserved BOOLEAN  
 7 Reserved BOOLEAN  
 8 Reserved BOOLEAN  
 9 Reserved BOOLEAN  
 10 Reserved BOOLEAN  
 11 Reserved BOOLEAN  
 12 UOB Auxiliary wiring not correct BOOLEAN 1= UOB Aux wiring is not correct  
 13 Reserved BOOLEAN  
 14 Reserved BOOLEAN  
 15 Reserved BOOLEAN  
 40010 0x0009 9 Alarm Register 1  
 0 Reserved BOOLEAN  
 1 Reserved BOOLEAN  
 2 Reserved BOOLEAN  
 3 Reserved BOOLEAN  
 4 Load bank breaker closed, parallel test mode enabled BOOLEAN 1=Load bank breaker closed, parallel test mode enabled  
 5 Reserved BOOLEAN  
 6 Reserved BOOLEAN  
 7 Reserved BOOLEAN  
 8 Reserved BOOLEAN  
 9 Unit Unit Breaker (UIB) open BOOLEAN 1=Unit Unit Breaker (UIB) open  
 10 Unit Ouput Breaker (UOB) open BOOLEAN 1=Unit Ouput Breaker (UOB) open  
 11 Maintenance Bypass Breaker (MBB) closed BOOLEAN 1=Maintenance Bypass Breaker (MBB) closed  
 12 System Isolation Breaker (SIB) open BOOLEAN 1=System Isolation Breaker (SIB) open  
 13 Static Switch Input Breaker (SSIB) open BOOLEAN 1=Static Switch Input Breaker (SSIB) open  
 14 Reserved BOOLEAN  
 15 Reserved BOOLEAN  
 40011 0x000A 10 Alarm Register 1  
 0 Reserved BOOLEAN  
 1 Reserved BOOLEAN  
 2 Reserved BOOLEAN  
 3 Reserved BOOLEAN  
 4 Reserved BOOLEAN  
 5 Reserved BOOLEAN  
 6 Reserved BOOLEAN  
 7 Reserved BOOLEAN  
 8 Static bypass switch inoperable BOOLEAN 1=Static bypass switch has a critical alarm that prevents it from operating  
 9 Static bypass switch warning BOOLEAN 1=Static bypass switch has an alarm with severity level warning

10 Reserved BOOLEAN  
 11 Reserved BOOLEAN  
 12 Reserved BOOLEAN  
 13 Reserved BOOLEAN  
 14 Reserved BOOLEAN  
 15 Reserved BOOLEAN  
 40012 0x000B 11 RESERVED 2  
 40014 0x000D 13 Alarm Register 1  
 0 Reserved BOOLEAN  
 1 Reserved BOOLEAN  
 2 Reserved BOOLEAN  
 Modicon  
 Standard  
 Register  
 Number  
 Absolute Starting Register Address,  
 (Hexa-decimal)  
 Absolute  
 Starting  
 Register  
 Address,  
 (Decimal)  
 Bit Data Point  
 Length  
 #  
 registers  
 Data Type  
 Multiply  
 Reading  
 By:  
 Divide Reading  
 By: Valid Response  
 Scale  
 3 Reserved BOOLEAN  
 4 Battery room ventilation inoperable BOOLEAN 1=Battery room ventilation inoperable  
 5 Reserved BOOLEAN  
 6 Reserved BOOLEAN  
 7 Reserved BOOLEAN  
 8 Reserved BOOLEAN  
 9 Reserved BOOLEAN  
 10 External battery monitoring alarm BOOLEAN 1=External battery monitoring alarm  
 11 Reserved BOOLEAN  
 12 Reserved BOOLEAN

13 Reserved BOOLEAN  
 14 Reserved BOOLEAN  
 15 Reserved BOOLEAN  
 40015 0x000E 14 Alarm Register 1 BOOLEAN  
 0 Reserved BOOLEAN  
 1 Reserved BOOLEAN  
 2 Reserved BOOLEAN  
 3 High Battery Temperature Level BOOLEAN 1=Battery temperature above alarm setting  
 4 Low Battery Temperature Level BOOLEAN 1=Battery temperature below alarm setting  
 5 Reserved BOOLEAN  
 6 Reserved BOOLEAN  
 7 Reserved BOOLEAN  
 8 Reserved BOOLEAN  
 9 Reserved BOOLEAN  
 10 Reserved BOOLEAN  
 11 Battery breaker BB1 open BOOLEAN 1=Battery breaker BB1 open  
 12 Battery breaker BB2 open BOOLEAN 1=Battery breaker BB2 open  
 13 Battery breaker BB3 open BOOLEAN 1=Battery breaker BB3 open  
 14 Battery breaker BB4 open BOOLEAN 1=Battery breaker BB4 open  
 15 Delayed transfer from Battery to Normal Operation BOOLEAN 1=The delayed transfer  
 from Battery to Normal Operation is active.  
 40016 0x000F 15 Alarm Register 1  
 0 Reserved BOOLEAN  
 1 Reserved BOOLEAN  
 2 Reserved BOOLEAN  
 3 Reserved BOOLEAN  
 4 Reserved BOOLEAN  
 5 Reserved BOOLEAN  
 6 Reserved BOOLEAN  
 7 Reserved BOOLEAN  
 8 Reserved BOOLEAN  
 9 Breaker BF2 open BOOLEAN 1= breaker BF2 open  
 10 Reserved BOOLEAN  
 11 Reserved BOOLEAN  
 12 Reserved BOOLEAN  
 13 Reserved BOOLEAN  
 14 Li-Ion AC Supply Breaker BMS:B1/BMS:B2 open BOOLEAN 1=Li-Ion AC Supply Breaker  
 BMS:B1/BMS:B2 open  
 15 Reserved BOOLEAN  
 40017 0x0010 16 Alarm Register 1  
 0 UPS operation mode - Static bypass standby BOOLEAN 1=UPS operation mode - Static  
 bypass standby  
 1 UPS operation mode - Inverter standby BOOLEAN 1=UPS operation mode - Inverter  
 standby

2 Reserved BOOLEAN  
 3 Reserved BOOLEAN  
 4 General UPS settings incorrect BOOLEAN 1=General UPS settings incorrect  
 5 UPS configuration incorrect BOOLEAN 1=UPS general configuration is incorrect  
 6 Synchronization unavailable BOOLEAN 1=Synchronization unavailable - system is free running  
 7 Fan inoperable BOOLEAN 1=UPS has one or more inoperable fans. Fan redundancy is lost.  
 8 Inverter is Off due to a request by the user BOOLEAN 1= Inverter is Off due to a request by the user  
 9 Restricted air flow BOOLEAN 1=Restricted air flow  
 10 Surveillance detected a fault BOOLEAN 1=Surveillance detected a fault  
 11 Charger status BOOLEAN 1=Inoperable  
 12 Inverter status BOOLEAN 1=Inoperable  
 13 PFC status BOOLEAN 1=Inoperable  
 14 Battery status BOOLEAN 1=Inoperable  
 15 Reserved BOOLEAN  
 40018 0x0011 17 Alarm Register 1  
 0 Technical check recommended BOOLEAN 1=Technical check recommended  
 1 Start-up recommended BOOLEAN 1= Secure start-up recommended  
 2 Warranty expiring soon BOOLEAN 1=Warranty expiring soon  
 3 Reserved BOOLEAN  
 Modicon  
 Standard  
 Register  
 Number  
 Absolute Starting Register Address,  
 (Hexa-decimal)  
 Absolute  
 Starting  
 Register  
 Address,  
 (Decimal)  
 Bit Data Point  
 Length  
 #  
 register  
 s  
 Data Type  
 Multiply  
 Reading  
 By:  
 Divide Reading  
 By: Valid Response  
 Scale

4	Air filter check recommended	BOOLEAN 1=Air filter check recommended
5	Reserved	BOOLEAN
6	Reserved	BOOLEAN
7	Reserved	BOOLEAN
8	Reserved	BOOLEAN
9	Reserved	BOOLEAN
10	Reserved	BOOLEAN
11	Reserved	BOOLEAN
12	Reserved	BOOLEAN
13	Reserved	BOOLEAN
14	Reserved	BOOLEAN
15	Reserved	BOOLEAN
40019	0x0012 18	RESERVED 1
40020	0x0013 19	Alarm Register 1
0	Reserved	BOOLEAN
1	Reserved	BOOLEAN
2	Reserved	BOOLEAN
3	Reserved	BOOLEAN
4	Reserved	BOOLEAN
5	Not enough UPSs ready to turn on inverter	BOOLEAN 1=Not enough UPSs ready to turn on inverter
6	Parallel UPS 1 not present	BOOLEAN 1=Parallel UPS 1 not present
7	Parallel UPS 2 not present	BOOLEAN 1=Parallel UPS 2 not present
8	Parallel UPS 3 not present	BOOLEAN 1=Parallel UPS 3 not present
9	Parallel UPS 4 not present	BOOLEAN 1=Parallel UPS 4 not present
10	Parallel UPS 5 not present	BOOLEAN 1=Parallel UPS 5 not present
11	Parallel mixed operation mode	BOOLEAN 1=Parallel mixed operation mode
12	Firmware versions in parallel UPS units are not identical	BOOLEAN 1=Firmware versions in parallel UPS units are not identical
13	Reserved	BOOLEAN
14	Reserved	BOOLEAN
15	Reserved	BOOLEAN
40021	0x0014 20	RESERVED 1
40022	0x0015 21	Alarm Register 1
0	System operation mode - Off	BOOLEAN 1 = System operation mode - Off
1	System operation mode - Forced static bypass	BOOLEAN 1 = System operation mode - Forced static bypass
2	System operation mode - Requested static bypass	BOOLEAN 1 = System operation mode - Requested static bypass
3	System operation mode - Maintenance bypass	BOOLEAN 1 = System operation mode - Maintenance bypass
4	System operation mode - Static Bypass Standby	BOOLEAN 1 = System operation mode - Static Bypass Standby
5	Reserved	BOOLEAN

6 Reserved BOOLEAN  
 7 Reserved BOOLEAN  
 8 Reserved BOOLEAN  
 9 Reserved BOOLEAN  
 10 Reserved BOOLEAN  
 11 Reserved BOOLEAN  
 12 Reserved BOOLEAN  
 13 Reserved BOOLEAN  
 14 Reserved BOOLEAN  
 15 Reserved BOOLEAN

#### 40023 0x0016 22 Alarm Register 1

- 0 Input missing phase BOOLEAN 1=Input is missing a phase
- 1 Bypass missing phase BOOLEAN 1=Bypass input is missing a phase
- 2 External sync voltage out of range BOOLEAN 1=External sync voltage is out of range
- 3 External sync phase sequence incorrect BOOLEAN 1=The phase rotation on external sync is wrong
- 4 External sync frequency out of range BOOLEAN 1=External sync frequency is out of range
- 5 External sync missing phase BOOLEAN 1=External sync is missing a phase
- 6 External sync temporarily disabled BOOLEAN 1=External sync temporarily disabled
- 7 Flywheel inoperable BOOLEAN 1=Flywheel inoperable
- 8 Display firmware incompatibility detected BOOLEAN 1=Display firmware incompatibility detected
- 9 NMC 1 firmware incompatibility detected BOOLEAN 1=NMC 1 firmware incompatibility detected
- 10 NMC 2 firmware incompatibility detected BOOLEAN 1=NMC 2 firmware incompatibility detected
- 11 10-Inch display incompatibility detected BOOLEAN 1=10 inch Display firmware incompatibility detected
- 12 Inverter output is not in phase with bypass input BOOLEAN 1=Inverter output is not in phase with bypass input
- 13 Engineering Firmware Version detected BOOLEAN 1=Alarm Engineering Firmware Version detected
- 14 Reserved BOOLEAN
- 15 Reserved BOOLEAN

#### 40024 0x0017 23 Alarm Register 1

0 Reserved BOOLEAN  
 1 Reserved BOOLEAN

Modicon  
 Standard  
 Register  
 Number

Absolute Starting Register Address,  
 (Hexa-decimal)  
 Absolute

	Starting Register Address, (Decimal)
	Bit Data Point Length # register s
	Data Type Multiply Reading By: Divide Reading By: Valid Response Scale
	2 Reserved BOOLEAN
	3 Reserved BOOLEAN
	4 Reserved BOOLEAN
	5 Reserved BOOLEAN
	6 Reserved BOOLEAN
	7 Reserved BOOLEAN
	8 Reserved BOOLEAN
	9 Reserved BOOLEAN
	10 Reserved BOOLEAN
	11 Reserved BOOLEAN
	12 Reserved BOOLEAN
	13 Reserved BOOLEAN
	14 Reserved BOOLEAN
	15 Reserved BOOLEAN
40025 0x0018 24	Alarm Register 1
	0 Reserved BOOLEAN
	1 Reserved BOOLEAN
	2 Reserved BOOLEAN
	3 Reserved BOOLEAN
	4 Reserved BOOLEAN
	5 Reserved BOOLEAN
	6 Reserved BOOLEAN
	7 Reserved BOOLEAN
	8 Reserved BOOLEAN
	9 Reserved BOOLEAN
	10 Reserved BOOLEAN
	11 Reserved BOOLEAN
	12 Reserved BOOLEAN

13	Reserved	BOOLEAN
14	Reserved	BOOLEAN
15	Reserved	BOOLEAN
40026	0x0019	25 Alarm Register 1
0	Sensor AP9810 - Input contact A in sensor 1	BOOLEAN 1 = Alarm from sensor 1 / contact A
1	Sensor AP9810 - Input contact B in sensor 1	BOOLEAN 1 = Alarm from sensor 1 / contact B
2	Sensor AP9810 - Input contact A in sensor 2	BOOLEAN 1 = Alarm from sensor 2 / contact A
3	Sensor AP9810 - Input contact B in sensor 2	BOOLEAN 1 = Alarm from sensor 2 / contact B
4	Sensor AP9335T or AP9335TH - temperature alarm in sensor 1	BOOLEAN 1 = temperature alarm in sensor 1
5	Sensor AP9335T or AP9335TH - temperature alarm in sensor 2	BOOLEAN 1 = temperature alarm in sensor 2
6	Sensor AP9335TH - humidity alarm in sensor 1	BOOLEAN 1 = humidity alarm in sensor 1
7	Sensor AP9335TH - humidity alarm in sensor 2	BOOLEAN 1 = humidity alarm in sensor 2
8	Sensor Communication Lost with sensor 1	BOOLEAN 1 = communication lost with sensor 1
9	Sensor Communication Lost with sensor 2	BOOLEAN 1 = communication lost with sensor 2
10	Reserved	BOOLEAN
11	Reserved	BOOLEAN
12	Reserved	BOOLEAN
13	Reserved	BOOLEAN
14	Reserved	BOOLEAN
15	Reserved	BOOLEAN
40027	0x0020	26 Alarm Register 1
0	Power Cabinet 1 surveillance detected a fault	BOOLEAN 1 = Power Cabinet 1 surveillance detected a fault
1	Power Cabinet 2 surveillance detected a fault	BOOLEAN 1 = Power Cabinet 2 surveillance detected a fault
2	Power Cabinet 3 surveillance detected a fault	BOOLEAN 1 = Power Cabinet 3 surveillance detected a fault
3	Power Cabinet 4 surveillance detected a fault	BOOLEAN 1 = Power Cabinet 4 surveillance detected a fault
4	Power Cabinet 5 surveillance detected a fault	BOOLEAN 1 = Power Cabinet 5 surveillance detected a fault
5	Power Cabinet 6 surveillance detected a fault	BOOLEAN 1 = Power Cabinet 6 surveillance detected a fault
6	Power Cabinet 7 surveillance detected a fault	BOOLEAN 1 = Power Cabinet 7 surveillance detected a fault
7	Reserved	BOOLEAN
8	Power Cabinet 1 inoperable	BOOLEAN 1 = Power cabinet inoperable
9	Power Cabinet 2 inoperable	BOOLEAN 1 = Power cabinet inoperable
10	Power Cabinet 3 inoperable	BOOLEAN 1 = Power cabinet inoperable
11	Power Cabinet 4 inoperable	BOOLEAN 1 = Power cabinet inoperable
12	Power Cabinet 5 inoperable	BOOLEAN 1 = Power cabinet inoperable
13	Power Cabinet 6 inoperable	BOOLEAN 1 = Power cabinet inoperable

14	Power Cabinet 7 inoperable	BOOLEAN 1 = Power cabinet inoperable
15	Reserved	BOOLEAN
40028 0x0021 27	Alarm Register	1
0	Input dry contact: Genset supplying UPS	BOOLEAN 1= a Genset supply the UPS
1	Input dry contact: Battery room ventilation inoperable	BOOLEAN 1= Battery room ventilation inoperable
2	Input dry contact: External battery monitoring inoperable	BOOLEAN 1= External battery monitoring inoperable
	Modicon	
	Standard	
	Register	
	Number	
	Absolute Starting Register Address,	
	(Hexa-decimal)	
	Absolute	
	Starting	
	Register	
	Address,	
	(Decimal)	
	Bit Data Point	
	Length	
	#	
	register	
	s	
	Data Type	
	Multiply	
	Reading	
	By:	
	Divide Reading	
	By: Valid Response	
	Scale	
3	Input dry contact: Ground fault detected	BOOLEAN 1= Ground fault detected
4	Input dry contact: UPS locked in static bypass mode is	
	activated	BOOLEAN 1= UPS locked in static bypass mode is activated
5	Input dry contact: User-defined input dry contacts 1	BOOLEAN 1= User-defined input dry contacts 1, in alarm position
6	Input dry contact: User-defined input dry contacts 2	BOOLEAN 1= User-defined input dry contacts 2, in alarm position
7	Input dry contact: Flywheel inoperable	BOOLEAN 1= Flywheel inoperable
8	Input dry contact: External energy storage monitoring	
	major alarm	BOOLEAN
	1= External energy storage monitoring major alarm	

9

Input dry contact: External energy storage monitoring  
minor alarm BOOLEAN

1= External energy storage monitoring minor alarm

10 Input dry contact: Force Charger Off BOOLEAN 1= Force Charger Off

11 Input dry contact: Disable High Efficiency Mode BOOLEAN 1= Disable High Efficiency  
Mode

12

Input dry contact: Transfer from Battery to Normal

Operation delay BOOLEAN 1=Transfer from Battery to Normal Operation delay

13 Input dry contact: Force Battery Operation BOOLEAN 1=Force Battery Operation

14 Input dry contact: Request Bypass operation BOOLEAN 1=Requested Bypass command  
from input relay activated

15 Reserved BOOLEAN

40029 0x0022 28 Alarm Register 1

0 Power Cabinet 1 surveillance fault BOOLEAN 1 = Temporized Power Cabinet surveillance  
fault

1 Power Cabinet 1 inoperable BOOLEAN 1 = Temporized Power Cabinet inoperable

2 Power Cabinet 1 - Power Bloc L1A - Surveillance fault BOOLEAN 1 = Power Bloc from  
Power Cabinet Surveillance fault

3 Power Cabinet 1 - Power Bloc L2A - Surveillance fault BOOLEAN 1 = Power Bloc from  
Power Cabinet Surveillance fault

4 Power Cabinet 1 - Power Bloc L3A - Surveillance fault BOOLEAN 1 = Power Bloc from  
Power Cabinet Surveillance fault

5 Power Cabinet 1 - Power Bloc L1B - Surveillance fault BOOLEAN 1 = Power Bloc from  
Power Cabinet Surveillance fault

6 Power Cabinet 1 - Power Bloc L2B - Surveillance fault BOOLEAN 1 = Power Bloc from  
Power Cabinet Surveillance fault

7 Power Cabinet 1 - Power Bloc L3B - Surveillance fault BOOLEAN 1 = Power Bloc from  
Power Cabinet Surveillance fault

8 Power Cabinet 2 surveillance fault BOOLEAN 1 = Temporized Power Cabinet surveillance  
fault

9 Power Cabinet 2 inoperable BOOLEAN 1 = Temporized Power Cabinet inoperable

10 Power Cabinet 2 - Power Bloc L1A - Surveillance fault BOOLEAN 1 = Power Bloc from  
Power Cabinet Surveillance fault

11 Power Cabinet 2 - Power Bloc L2A - Surveillance fault BOOLEAN 1 = Power Bloc from  
Power Cabinet Surveillance fault

12 Power Cabinet 2 - Power Bloc L3A - Surveillance fault BOOLEAN 1 = Power Bloc from  
Power Cabinet Surveillance fault

13 Power Cabinet 2 - Power Bloc L1B - Surveillance fault BOOLEAN 1 = Power Bloc from  
Power Cabinet Surveillance fault

14 Power Cabinet 2 - Power Bloc L2B - Surveillance fault BOOLEAN 1 = Power Bloc from  
Power Cabinet Surveillance fault

15 Power Cabinet 2 - Power Bloc L3B - Surveillance fault BOOLEAN 1 = Power Bloc from

Power Cabinet Surveillance fault  
40030 0x0023 29 Alarm Register 1

0 Power Cabinet 3 surveillance fault BOOLEAN 1 = Temporized Power Cabinet surveillance fault

1 Power Cabinet 3 inoperable BOOLEAN 1 = Temporized Power Cabinet inoperable

2 Power Cabinet 3 - Power Bloc L1A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault

3 Power Cabinet 3 - Power Bloc L2A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault

4 Power Cabinet 3 - Power Bloc L3A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault

5 Power Cabinet 3 - Power Bloc L1B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault

6 Power Cabinet 3 - Power Bloc L2B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault

7 Power Cabinet 3 - Power Bloc L3B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault

8 Power Cabinet 4 surveillance fault BOOLEAN 1 = Temporized Power Cabinet surveillance fault

9 Power Cabinet 4 inoperable BOOLEAN 1 = Temporized Power Cabinet inoperable

10 Power Cabinet 4 - Power Bloc L1A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault

11 Power Cabinet 4 - Power Bloc L2A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault

12 Power Cabinet 4 - Power Bloc L3A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault

13 Power Cabinet 4 - Power Bloc L1B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault

14 Power Cabinet 4 - Power Bloc L2B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault

15 Power Cabinet 4 - Power Bloc L3B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault

40031 0x0024 30 Alarm Register 1

0 Power Cabinet 5 surveillance fault BOOLEAN 1 = Temporized Power Cabinet surveillance fault

1 Power Cabinet 5 inoperable BOOLEAN 1 = Temporized Power Cabinet inoperable

2 Power Cabinet 5 - Power Bloc L1A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault

3 Power Cabinet 5 - Power Bloc L2A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault

4 Power Cabinet 5 - Power Bloc L3A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault

5 Power Cabinet 5 - Power Bloc L1B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault

6 Power Cabinet 5 - Power Bloc L2B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault

7 Power Cabinet 5 - Power Bloc L3B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault

8 Power Cabinet 6 surveillance fault BOOLEAN 1 = Temporized Power Cabinet surveillance fault

9 Power Cabinet 6 inoperable BOOLEAN 1 = Temporized Power Cabinet inoperable

10 Power Cabinet 6 - Power Bloc L1A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault

11 Power Cabinet 6 - Power Bloc L2A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault

12 Power Cabinet 6 - Power Bloc L3A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault

13 Power Cabinet 6 - Power Bloc L1B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault

14 Power Cabinet 6 - Power Bloc L2B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault

15 Power Cabinet 6 - Power Bloc L3B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault

40032 0x0025 31 Alarm Register 1

Modicon  
Standard  
Register  
Number

Absolute Starting Register Address,  
(Hexa-decimal)

Absolute  
Starting  
Register  
Address,  
(Decimal)

Bit Data Point  
Length  
#  
register  
s

Data Type  
Multiply  
Reading  
By:  
Divide Reading  
By: Valid Response  
Scale

0 Power Cabinet 7 surveillance fault BOOLEAN 1 = Temporized Power Cabinet surveillance

fault

- 1 Power Cabinet 7 inoperable BOOLEAN 1 = Temporized Power Cabinet inoperable
  - 2 Power Cabinet 7 - Power Bloc L1A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault
  - 3 Power Cabinet 7 - Power Bloc L2A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault
  - 4 Power Cabinet 7 - Power Bloc L3A - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault
  - 5 Power Cabinet 7 - Power Bloc L1B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault
  - 6 Power Cabinet 7 - Power Bloc L2B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault
  - 7 Power Cabinet 7 - Power Bloc L3B - Surveillance fault BOOLEAN 1 = Power Bloc from Power Cabinet Surveillance fault
  - 8 Reserved BOOLEAN
  - 9 Surveillance Limit Detected on Power Cabinet 1 BOOLEAN 1= SurvLimitDetected on Power Cabinet 1
  - 10 Surveillance Limit Detected on Power Cabinet 2 BOOLEAN 1= SurvLimitDetected on Power Cabinet 2
  - 11 Surveillance Limit Detected on Power Cabinet 3 BOOLEAN 1= SurvLimitDetected on Power Cabinet 3
  - 12 Surveillance Limit Detected on Power Cabinet 4 BOOLEAN 1= SurvLimitDetected on Power Cabinet 4
  - 13 Surveillance Limit Detected on Power Cabinet 5 BOOLEAN 1= SurvLimitDetected on Power Cabinet 5
  - 14 Surveillance Limit Detected on Power Cabinet 6 BOOLEAN 1= SurvLimitDetected on Power Cabinet 6
  - 15 Surveillance Limit Detected on Power Cabinet 7 BOOLEAN 1= SurvLimitDetected on Power Cabinet 7
- Static Data
- 44097 0x1000 4096 Display/NMC Model Number 9 ASCII
  - 44106 0x1009 4105 Display/NMC Serial Number 8 ASCII
  - 44114 0x1011 4113 Display/NMC Firmware Revision APP 9 ASCII
  - 44123 0x101A 4122 Display/NMC Hardware Revision 9 ASCII
  - 44132 0x1023 4131 Display/NMC Date of Manufacture 6 ASCII
  - 44138 0x1029 4137 RESERVED 8
  - 44146 0x1031 4145 UPS Serial Number 6 ASCII
  - 44152 0x1037 4151 UPS Firmware Version 12 ASCII
  - 44164 0x1043 4163 Product Name 40 ASCII
  - 44204 0x106B 4203 UPS Serial Number for 14 characters 8 ASCII for new 3-phases UPS, using 14 characters
- Dynamic Data
- 44353 0x1100 4352 RESERVED 2
  - 44355 0x1102 4354 Runtime remaining 2 UINT32 1 1 Seconds

44357 0x1104 4356 Estimated charge time 2 UINT32 1 1 Seconds  
 44359 0x1106 4358 Estimated charge % 1 UINT16 1 1 %  
 44360 0x1107 4359 RESERVED 8  
 44368 0x110F 4367 Battery Temperature (for classic battery solution) 1 UINT16 1 1 °C or °F  
 44369 0x1110 4368 Charger Mode 1  
 0 Float Charging BOOLEAN 1=Charger mode is float charging  
 1 Boost Charging BOOLEAN 1=Charger mode is boost charging  
 2 Reserved BOOLEAN  
 3 Reserved BOOLEAN  
 4 Reserved BOOLEAN  
 5 Equalization Charging BOOLEAN 1=Charger mode is equalization charging  
 6 Not Charging BOOLEAN 1=Charger mode is Off  
 7 Test In Progress BOOLEAN 1=Test is in progress  
 8 Cyclic Charging BOOLEAN 1=Charge mode is cyclic charging  
 9 Reserved BOOLEAN  
 10 Reserved BOOLEAN  
 11 Reserved BOOLEAN  
 12 Reserved BOOLEAN  
 13 Reserved BOOLEAN  
 14 Reserved BOOLEAN  
 15 Reserved BOOLEAN  
 44370 0x1111 4369 Battery Power 1 UNIT16 0.1 10 kW  
 44371 0x1112 4370 RESERVED 1  
 44372 0x1113 4371 Battery Voltage 1 UINT16 0.1 10 Vdc  
 44373 0x1114 4372 Battery Current, for GVX up to 1000kVA 1 UNIT16 0.1 10  
 Amps - Caution overflow possible. There is a current limitation [– 3276A, 3276A].  
 That register can be use for GVX up to 1000KVA.  
 When GVX power rating exceed 1000 kVA (1250KVA and 1500kVA) used register  
 0x111D  
 44374 0x1115 4373 RESERVED 1 UINT16 1 1  
 44375 0x1116 4374 RESERVED 1 UINT16 1 1  
 44376 0x1117 4375 RESERVED 1 UINT16 1 1  
 44377 0x1118 4376 RESERVED 1 UINT16 1 1  
 44378 0x1119 4377 RESERVED 1 UINT16 1 1  
 44379 0x111A 4378 RESERVED 1 UINT16 1 1  
 44380 0x111B 4379 RESERVED 1 UINT16 1 1  
 44381 0x111C 4380 RESERVED 1 UINT16 1 1  
 Modicon  
 Standard  
 Register  
 Number  
 Absolute Starting Register Address,  
 (Hexa-decimal)  
 Absolute

Starting Register Address, (Decimal)	Bit Data Point Length # register s	Data Type	Multiply Reading By: Divide Reading By: Valid Response Scale
44382 0x111D 4381 Battery Current, for all GVX power rating (from 250kVA up to 1500kVA)	1	UNT16	1 1
Amps - Recommended register for GVX. To be used when UPS power rating exceed 1000 kVA. This register supports all GVX power rating (from 250KVA up to 1500kVA).			
44383 0x111E 4382 Battery Test Process Status ENUM			
0= Inactive 1= Battery Calibration is In Progress 2= Battery Calibration is Passed 5= Battery Calibration is Aborted			
44384 0x111F 4383 Battery Calibration Process Status ENUM			
0= Inactive 1= Battery Calibration is In Progress 2= Battery Calibration is Passed 5= Battery Calibration is Aborted			
44385 0x1120 4384 Battery Test Status ENUM			
0= Unknown 1= Battery OK 2= Battery CapacityReduced 3= Battery Defect			
44609 0x1200 4608 Frequency (input)	1	UINT16	0.1 10 Hz
44610 0x1201 4609 Voltage L1-2 (input)	1	UINT16	1 1 Volts
44611 0x1202 4610 Voltage L2-3 (input)	1	UINT16	1 1 Volts
44612 0x1203 4611 Voltage L3-1 (input)	1	UINT16	1 1 Volts
44613 0x1204 4612 Current L1 (input)	1	UINT16	1 1 amps
44614 0x1205 4613 Current L2 (input)	1	UINT16	1 1 amps
44615 0x1206 4614 Current L3 (input)	1	UINT16	1 1 amps
44616 0x1207 4615 Active power L1 (input)	1	UINT16	1 1 kW

44617 0x1208 4616 Active power L2 (input) 1 UINT16 1 1 kW  
 44618 0x1209 4617 Active power L3 (input) 1 UINT16 1 1 kW  
 44619 0x120A 4618 Apparent power L1 (input) 1 UINT16 1 1 kVA  
 44620 0x120B 4619 Apparent power L2 (input) 1 UINT16 1 1 kVA  
 44621 0x120C 4620 Apparent power L3 (input) 1 UINT16 1 1 kVA  
 44622 0x120D 4621 Total active power (input) 1 UINT16 1 1 kW  
 44623 0x120E 4622 Total apparent power (input) 1 UINT16 1 1 kVA  
 44624 0x120F 4623 Voltage L1-N (input) 1 UINT16 1 1 Volts  
 44625 0x1210 4624 Voltage L2-N (input) 1 UINT16 1 1 Volts  
 44626 0x1211 4625 Voltage L3-N (input) 1 UINT16 1 1 Volts  
 44627 0x1212 4626 Maximum RMS Current L1 (input) 2 UINT32 1 1 amps  
 44629 0x1214 4628 Maximum RMS Current L2 (input) 2 UINT32 1 1 amps  
 44631 0x1216 4630 Maximum RMS Current L3 (input) 2 UINT32 1 1 amps  
 44633 0x1218 4632 Power factor L1 (input) 1 UINT16 0.01 100 Unitless  
 44634 0x1219 4633 Power factor L2 (input) 1 UINT16 0.01 100 Unitless  
 44635 0x121A 4634 Power factor L3 (input) 1 UINT16 0.01 100 Unitless  
 44865 0x1300 4864 Frequency (bypass) 1 UINT16 0.1 10 Hz  
 44866 0x1301 4865 Voltage L1-2 (bypass) 1 UINT16 1 1 Volts  
 44867 0x1302 4866 Voltage L2-3 (bypass) 1 UINT16 1 1 Volts  
 44868 0x1303 4867 Voltage L3-1 (bypass) 1 UINT16 1 1 Volts  
 44869 0x1304 4868 Current L1 (bypass) 1 UINT16 1 1 amps  
 44870 0x1305 4869 Current L2 (bypass) 1 UINT16 1 1 amps  
 44871 0x1306 4870 Current L3 (bypass) 1 UINT16 1 1 amps  
 44872 0x1307 4871 Active power L1 (bypass) 1 UINT16 1 1 kW  
 44873 0x1308 4872 Active power L2 (bypass) 1 UINT16 1 1 kW  
 44874 0x1309 4873 Active power L3 (bypass) 1 UINT16 1 1 kW  
 44875 0x130A 4874 Apparent power L1 (bypass) 1 UINT16 1 1 kVA  
 44876 0x130B 4875 Apparent power L2 (bypass) 1 UINT16 1 1 kVA  
 44877 0x130C 4876 Apparent power L3 (bypass) 1 UINT16 1 1 kVA  
 44878 0x130D 4877 Total active power (bypass) 1 UINT16 1 1 kW  
 44879 0x130E 4878 Total apparent power (bypass) 1 UINT16 1 1 kVA  
 44880 0x130F 4879 Voltage L1-N (bypass) 1 UINT16 1 1 Volts  
 44881 0x1310 4880 Voltage L2-N (bypass) 1 UINT16 1 1 Volts  
 44882 0x1311 4881 Voltage L3-N (bypass) 1 UINT16 1 1 Volts  
 44883 0x1312 4882 Maximum RMS Current L1 (bypass) 2 UINT32 1 1 amps  
 44885 0x1314 4884 Maximum RMS Current L2 (bypass) 2 UINT32 1 1 amps  
 44887 0x1316 4886 Maximum RMS Current L3 (bypass) 2 UINT32 1 1 amps  
 44889 0x1318 4888 Power factor L1 (bypass) 1 UINT16 0.01 100 Unitless  
 44890 0x1319 4889 Power factor L2 (bypass) 1 UINT16 0.01 100 Unitless  
 44891 0x131A 4890 Power factor L3 (bypass) 1 UINT16 0.01 100 Unitless  
 44892 0x131B 4891 UTHD - Voltage THD L1 (bypass) 1 UINT16 0.1 10 %  
 44893 0x131C 4892 UTHD - Voltage THD L2 (bypass) 1 UINT16 0.1 10 %  
 44894 0x131D 4893 UTHD - Voltage THD L3 (bypass) 1 UINT16 0.1 10 %  
 45121 0x1400 5120 UPS Power Rating 1 UINT16 1 1 kVA

45122 0x1401 5121 Frequency (output) 1 UINT16 0.1 10 Hz  
 45123 0x1402 5122 Voltage L1-2 (output) 1 UINT16 1 1 Volts

Modicon  
 Standard  
 Register  
 Number

Absolute Starting Register Address,  
 (Hexa-decimal)

Absolute  
 Starting  
 Register  
 Address,  
 (Decimal)

Bit Data Point  
 Length

#

register  
 s

Data Type

Multiply

Reading

By:

Divide Reading

By: Valid Response

Scale

45124 0x1403 5123 Voltage L2-3 (output) 1 UINT16 1 1 Volts  
 45125 0x1404 5124 Voltage L3-1 (output) 1 UINT16 1 1 Volts  
 45126 0x1405 5125 Current L1 (output) 1 UINT16 1 1 amps  
 45127 0x1406 5126 Current L2 (output) 1 UINT16 1 1 amps  
 45128 0x1407 5127 Current L3 (output) 1 UINT16 1 1 amps  
 45129 0x1408 5128 Maximum RMS current L1 (output) 2 UINT32 1 1 amps  
 45131 0x140A 5130 Maximum RMS current L2 (output) 2 UINT32 1 1 amps  
 45133 0x140C 5132 Maximum RMS current L3 (output) 2 UINT32 1 1 amps  
 45135 0x140E 5134 Active power L1 (output) 1 UINT16 1 1 kW  
 45136 0x140F 5135 Active power L2 (output) 1 UINT16 1 1 kW  
 45137 0x1410 5136 Active power L3 (output) 1 UINT16 1 1 kW  
 45138 0x1411 5137 Apparent power L1 (output) 1 UINT16 1 1 kVA  
 45139 0x1412 5138 Apparent power L2 (output) 1 UINT16 1 1 kVA  
 45140 0x1413 5139 Apparent power L3 (output) 1 UINT16 1 1 kVA  
 45141 0x1414 5140 Apparent power percent L1 (output) 1 UINT16 0.1 10 %  
 45142 0x1415 5141 Apparent power percent L2 (output) 1 UINT16 0.1 10 %  
 45143 0x1416 5142 Apparent power percent L3 (output) 1 UINT16 0.1 10 %  
 45144 0x1417 5143 Total active power (output) 1 UINT16 1 1 kW  
 45145 0x1418 5144 Total apparent power (output) 1 UINT16 1 1 kVA

45146 0x1419 5145 Total Output Percent load 1 UINT16 0.1 10 %  
 45147 0x141A 5146 Power factor L1 (output) 1 UINT16 0.01 100 power factor  
 45148 0x141B 5147 Power factor L2 (output) 1 UINT16 0.01 100 power factor  
 45149 0x141C 5148 Power factor L3 (output) 1 UINT16 0.01 100 power factor  
 45150 0x141D 5149 Current crest factor L1 (output) 1 UINT16 0.1 10 crest factor  
 45151 0x141E 5150 Current crest factor L2 (output) 1 UINT16 0.1 10 crest factor  
 45152 0x141F 5151 Current crest factor L3 (output) 1 UINT16 0.1 10 crest factor  
 45153 0x1420 5152 Voltage L1-N (output) 1 UINT16 1 1 Volts  
 45154 0x1421 5153 Voltage L2-N (output) 1 UINT16 1 1 Volts  
 45155 0x1422 5154 Voltage L3-N (output) 1 UINT16 1 1 Volts  
 45156 0x1423 5155 Neutral current (output) 1 UINT16 1 1 amps  
 45157 0x1424 5156 Current THD L1 (output) 1 UINT16 0.1 10 %  
 45158 0x1425 5157 Current THD L2 (output) 1 UINT16 0.1 10 %  
 45159 0x1426 5158 Current THD L3 (output) 1 UINT16 0.1 10 %  
 45160 0x1427 5159 IOC Power Rating 1 UINT16 1 1 kVA  
 45161 0x1428 5160 Available UPS Power Rating 1 UINT16 1 1 kVA  
 45376 0x14FF 5375 RESERVED 1 UINT16 1 1  
 45377 0x1500 5376 IOC Ambient temperature 1 UINT16 1 1 °C or °F  
 45378 0x1501 5377 Switch gear status 1

Bit mask

For each bit,

0 = open, 1 =closed

0 Unit Input Breaker (UIB) BOOLEAN

1 Unit Output Breaker (UOB) BOOLEAN

2 Maintenance Bypass Breaker (MBB) BOOLEAN

3 System Isolation Breaker (SIB) BOOLEAN

4 Static Switch Input Breaker (SSIB) BOOLEAN

5 Battery Breaker 1 (for classic battery solution) BOOLEAN

6 Battery Breaker 2 (for classic battery solution) BOOLEAN

7 Battery Breaker 3 (for classic battery solution) BOOLEAN

8 Battery Breaker 4 (for classic battery solution) BOOLEAN

9 BF2 BOOLEAN

10 Reserved BOOLEAN

11 Reserved BOOLEAN

12 Reserved BOOLEAN

13 Reserved BOOLEAN

14 Reserved BOOLEAN

15 Reserved BOOLEAN

Modicon

Standard

Register

Number

Absolute Starting Register Address,  
 (Hexa-decimal)

			Absolute Starting Register Address, (Decimal)	
			Bit Data Point Length # register s	
			Data Type Multiply Reading By: Divide Reading By: Valid Response Scale	
45379	0x1502	5378	UPS Operation Mode 1 ENUM	
			1 = Normal operation	
			2 = Battery Operation	
			3 = Battery Test	
			4 = Requested Static Bypass	
			5 = Forced Static Bypass	
			6 = Maintenance Bypass	
			7 = Off	
			8 = Emergency Static Bypass	
			9 = Static Bypass Standby	
			10 = Inverter Standby	
			11 = Power Saving Mode	
			12 = Inverter SPoT Mode	
			13 = ECO Mode	
			14 = EConversion	
45380	0x1503	5379	Number of Active Alarms 1 UINT16 1 1	Number of active alarms in the system
45381	0x1504	5380	Highest alarm severity 1 UINT16 1 1	
			0 = none	
			1 = informational	
			2 = warning	
			3 = critical	
45382	0x1505	5381	System Mode 1 ENUM	
			1 = Inverter	
			2 = Requested Static Bypass	
			3 = Forced Static Bypass	
			4 = Off	

5 = Reserved  
 6 = Maintenance Bypass  
 7 = ECO Mode  
 45383 0x1506 5382 RESERVED 3  
 45385 0x1508 5384 UPS Redundancy Status 1 UINT16 1 1  
 45386 0x1509 5385 NMC/UPS Time 4 ASCII hh:mm:ss format  
 45390 0x150D 5389 NMC/UPS Date 5 ASCII mm/dd/yyyy format  
 45395 0x1512 5394 Input kWh 2 UINT32 1 1 kWh  
 45397 0x1514 5396 Output kWh 2 UINT32 1 1 kWh  
 45399 0x1516 5398 IOC Exhaust Air Temperature 1 UINT16 1 1 °C or °F  
 45400 0x1517 5399 Ambient Temperature from Power Cabinet [1] 1 UINT16 1 1 °C or °F  
 45401 0x1518 5400 Exhaust Temperature from Power Cabinet [1] 1 UINT16 1 1 °C or °F  
 45402 0x1519 5401 Ambient Temperature from Power Cabinet [2] 1 UINT16 1 1 °C or °F  
 45403 0x151A 5402 Exhaust Temperature from Power Cabinet [2] 1 UINT16 1 1 °C or °F  
 45404 0x151B 5403 Ambient Temperature from Power Cabinet [3] 1 UINT16 1 1 °C or °F  
 45405 0x151C 5404 Exhaust Temperature from Power Cabinet [3] 1 UINT16 1 1 °C or °F  
 45406 0x151D 5405 Ambient Temperature from Power Cabinet [4] 1 UINT16 1 1 °C or °F  
 45407 0x151E 5406 Exhaust Temperature from Power Cabinet [4] 1 UINT16 1 1 °C or °F  
 45408 0x151F 5407 Ambient Temperature from Power Cabinet [5] 1 UINT16 1 1 °C or °F  
 45409 0x1520 5408 Exhaust Temperature from Power Cabinet [5] 1 UINT16 1 1 °C or °F  
 45410 0x1521 5409 Ambient Temperature from Power Cabinet [6] 1 UINT16 1 1 °C or °F  
 45411 0x1522 5410 Exhaust Temperature from Power Cabinet [6] 1 UINT16 1 1 °C or °F  
 45412 0x1523 5411 Ambient Temperature from Power Cabinet [7] 1 UINT16 1 1 °C or °F  
 45413 0x1524 5412 Exhaust Temperature from Power Cabinet [7] 1 UINT16 1 1 °C or °F  
 45414 0x1525 5413 Power Cabinet Redundancy Status 1 UINT16 1 1 0 - 7  
 46401 0x1900 6400 Current L1 (parallel system mains input) 1 UINT16 1 1 amps  
 46402 0x1901 6401 Current L2 (parallel system mains input) 1 UINT16 1 1 amps  
 46403 0x1902 6402 Current L3 (parallel system mains input) 1 UINT16 1 1 amps  
 46404 0x1903 6403 Current L1 (parallel system bypass input) 1 UINT16 1 1 amps  
 46405 0x1904 6404 Current L2 (parallel system bypass input) 1 UINT16 1 1 amps  
 46406 0x1905 6405 Current L3 (parallel system bypass input) 1 UINT16 1 1 amps  
 46407 0x1906 6406 Current L1 (parallel system output) 1 UINT16 1 1 amps  
 46408 0x1907 6407 Current L2 (parallel system output) 1 UINT16 1 1 amps  
 46409 0x1908 6408 Current L3 (parallel system output) 1 UINT16 1 1 amps  
 46410 0x1909 6409 Total apparent power (parallel system output) 1 UINT16 1 1 kVA  
 46411 0x190A 6410 Total Percent load (parallel system) 1 UINT16 0.1 10 %  
 46412 0x190B 6411 Total active power (parallel system output) 1 UINT16 1 1 kW  
 46413 0x190C 6412 Apparent power percent L1 (parallel system output) 1 UINT16 0.1 10 %  
 46414 0x190D 6413 Apparent power percent L2 (parallel system output) 1 UINT16 0.1 10 %  
 46415 0x190E 6414 Apparent power percent L3 (parallel system output) 1 UINT16 0.1 10 %  
 46416 0x190F 6415 Reserved  
 46417 0x1910 6416 Reserved  
 46418 0x1911 6417 Reserved  
 46419 0x1912 6418 Reserved

46420 0x1913 6419 UPS Operation Modes 1 bit = 1, define current UPS operation mode

Modicon

Standard

Register

Number

Absolute Starting Register Address,  
(Hexa-decimal)

Absolute

Starting

Register

Address,

(Decimal)

Bit Data Point

Length

#

register

s

Data Type

Multiply

Reading

By:

Divide Reading

By: Valid Response

Scale

0 Initialize BOOLEAN

1 Normal Operation BOOLEAN

2 Battery Operation BOOLEAN

3 Battery test or Battery Discharge in Spot Mode BOOLEAN

4 Requested Static Bypass BOOLEAN

5 Forced Static Bypass BOOLEAN

6 Maintenance Bypass BOOLEAN

7 Off BOOLEAN

8 Emergency Static Bypass BOOLEAN

9 Static Bypass Standby BOOLEAN

10 Inverter standby BOOLEAN

11 Power Saving mode BOOLEAN

12 Inverter SPoT Mode BOOLEAN

13 ECO mode BOOLEAN

14 EConversion Mode mode BOOLEAN

15 Charger SPoT Mode BOOLEAN

46421 0x1914 6420 System Mode 1 bit = 1, define current System mode

0 Inverter BOOLEAN

1 Requested Static Bypass BOOLEAN

2 Forced Static Bypass BOOLEAN

3 Off BOOLEAN  
 4 Maintenance Bypass BOOLEAN  
 5 ECO mode BOOLEAN  
 6 EConversion mode BOOLEAN  
 7 Static Bypass Standby Operation BOOLEAN  
 8 Reserved BOOLEAN  
 9 Reserved BOOLEAN  
 10 Reserved BOOLEAN  
 11 Reserved BOOLEAN  
 12 Reserved BOOLEAN  
 13 Reserved BOOLEAN  
 14 Reserved BOOLEAN  
 15 Reserved BOOLEAN  
 46422 0x1915 6421 Reserved 1 UINT16 1 1  
 46423 0x1916 6422 Reserved 1 UINT16 1 1  
 46424 0x1917 6423 Reserved 1 UINT16 1 1  
 46425 0x1918 6424 Reserved 1 UINT16 1 1  
 46426 0x1919 6425 Reserved 1 UINT16 1 1  
 46427 0x191A 6426 Reserved 1 UINT16 1 1  
 46428 0x191B 6427 Reserved 1 UINT16 1 1  
 46429 0x191C 6428 Reserved 1 UINT16 1 1  
 46430 0x191D 6429 Reserved 1 UINT16 1 1  
 46431 0x191E 6430 Sensor temperature in sensor 1 1 UINT16 0.1 10 °C or °F  
 46432 0x191F 6431 Sensor temperature in sensor 2 1 UINT16 0.1 10 °C or °F  
 46433 0x1920 6432 Sensor humidity in sensor 1 1 UINT16 0.1 10 %  
 46434 0x1921 6433 Sensor humidity in sensor 2 1 UINT16 0.1 10 %  
 46435 0x1922 6434 Sensor (AP9810) input contact status 1  
 Bit mask  
 For each bit,  
 0 = open, 1 =closed  
 0 Sensor dry contact A in sensor 1 BOOLEAN  
 1 Sensor dry contact B in sensor 1 BOOLEAN  
 2 Sensor dry contact A in sensor 2 BOOLEAN  
 3 Sensor dry contact B in sensor 2 BOOLEAN  
 4 Reserved BOOLEAN  
 5 Reserved BOOLEAN  
 6 Reserved BOOLEAN  
 7 Reserved BOOLEAN  
 8 Reserved BOOLEAN  
 9 Reserved BOOLEAN  
 10 Reserved BOOLEAN  
 11 Reserved BOOLEAN  
 12 Reserved BOOLEAN  
 13 Reserved BOOLEAN

14 Reserved BOOLEAN  
 15 Reserved BOOLEAN  
 46449 0x1930 6448 User interface - Input Pictogram  
     1 UINT16 1 1  
         Inoperable (Red) = 4  
         Ok and operating (Green) = 2  
         None of the above (Black) = 0  
             Modicon  
             Standard  
             Register  
             Number  
 Absolute Starting Register Address,  
     (Hexa-decimal)  
         Absolute  
         Starting  
         Register  
         Address,  
         (Decimal)  
 Bit Data Point  
     Length  
         #  
         register  
         s  
     Data Type  
     Multiply  
     Reading  
     By:  
         Divide Reading  
     By: Valid Response  
         Scale  
 46450 0x1931 6449 User interface - PFC Pictogram  
     1 UINT16 1 1  
         Inoperable (Red) = 4  
         Ok and operating (Green) = 2  
         None of the above (Black) = 0  
 46451 0x1932 6450 User interface - Battery Pictogram  
     1 UINT16 1 1  
         Inoperable (Red) = 4  
         Ok and operating (Green) = 2  
         None of the above (Black) = 0  
 46452 0x1933 6451 User interface - Inverter Pictogram  
     1 UINT16 1 1  
         Inoperable (Red) = 4  
         Ok and operating (Green) = 2

None of the above (Black) = 0  
 46453 0x1934 6452 User interface - Output Pictogram  
     1 UINT16 1 1  
     Inoperable (Red) = 4  
     Ok and operating (Green) = 2  
     None of the above (Black) = 0  
 46454 0x1935 6453 User interface - Bypass Input Pictogram  
     1 UINT16 1 1  
     Inoperable (Red) = 4  
     Ok and operating (Green) = 2  
     None of the above (Black) = 0  
 46455 0x1936 6454 User interface - Static Bypass Pictogram  
     1 UINT16 1 1  
     Inoperable (Red) = 4  
     Ok and operating (Green) = 2  
     None of the above (Black) = 0  
 46456 0x1937 6455 Status for mimic animation 1 UINT16 1 1  
 0 Aggregated Battery circuit breaker status BOOLEAN 0 = open, 1 =closed  
     1 Reserved BOOLEAN  
     2 Reserved BOOLEAN  
     3 Reserved BOOLEAN  
     4 Reserved BOOLEAN  
     5 Reserved BOOLEAN  
     6 Reserved BOOLEAN  
     7 Reserved BOOLEAN  
     8 Reserved BOOLEAN  
     9 Reserved BOOLEAN  
     10 Reserved BOOLEAN  
     11 Reserved BOOLEAN  
     12 Reserved BOOLEAN  
     13 Reserved BOOLEAN  
     14 Reserved BOOLEAN  
     15 Reserved BOOLEAN  
 46457 0x1938 6456 Power Cabinet status for UPS detailed view animation 1 UINT16 1 1  
 0 Warning alarm present in Power Cabinet 1 BOOLEAN 1 = warning alarm present in Power  
     Cabinet 1 (Orange)  
     1 Critical alarm present in Power Cabinet 1 BOOLEAN 1 = critical alarm present Power  
         Cabinet 1 (Red)  
 2 Warning alarm present in Power Cabinet 2 BOOLEAN 1 = warning alarm present in Power  
     Cabinet 2 (Orange)  
     3 Critical alarm present in Power Cabinet 2 BOOLEAN 1 = critical alarm present Power  
         Cabinet 2 (Red)  
 4 Warning alarm present in Power Cabinet 3 BOOLEAN 1 = warning alarm present in Power  
     Cabinet 3 (Orange)

5 Critical alarm present in Power Cabinet 3 BOOLEAN 1 = critical alarm present Power Cabinet 3 (Red)

6 Warning alarm present in Power Cabinet 4 BOOLEAN 1 = warning alarm present in Power Cabinet 4 (Orange)

7 Critical alarm present in Power Cabinet 4 BOOLEAN 1 = critical alarm present Power Cabinet 4 (Red)

8 Warning alarm present in Power Cabinet 5 BOOLEAN 1 = warning alarm present in Power Cabinet 5 (Orange)

9 Critical alarm present in Power Cabinet 5 BOOLEAN 1 = critical alarm present Power Cabinet 5 (Red)

10 Warning alarm present in Power Cabinet 6 BOOLEAN 1 = warning alarm present in Power Cabinet 6 (Orange)

11 Critical alarm present in Power Cabinet 6 BOOLEAN 1 = critical alarm present Power Cabinet 6 (Red)

12 Warning alarm present in Power Cabinet 7 BOOLEAN 1 = warning alarm present in Power Cabinet 7 (Orange)

13 Critical alarm present in Power Cabinet 7 BOOLEAN 1 = critical alarm present Power Cabinet 7 (Red)

14 Reserved BOOLEAN

15 Reserved BOOLEAN

46458 0x1939 6457 Power Cabinet status for UPS detailed view animation 1 UINT16 1 1

0 informational alarm present in Power Cabinet 1 BOOLEAN 1 = informational alarm present in Power Cabinet 1

1 informational alarm present in Power Cabinet 2 BOOLEAN 2 = informational alarm present in Power Cabinet 2

2 informational alarm present in Power Cabinet 3 BOOLEAN 3 = informational alarm present in Power Cabinet 3

3 informational alarm present in Power Cabinet 4 BOOLEAN 4 = informational alarm present in Power Cabinet 4

4 informational alarm present in Power Cabinet 5 BOOLEAN 5 = informational alarm present in Power Cabinet 5

5 informational alarm present in Power Cabinet 6 BOOLEAN 6 = informational alarm present in Power Cabinet 6

6 informational alarm present in Power Cabinet 7 BOOLEAN 7 = informational alarm present in Power Cabinet 7

7 Reserved BOOLEAN

8 Reserved BOOLEAN

9 Reserved BOOLEAN

10 Reserved BOOLEAN

11 Reserved BOOLEAN

12 Reserved BOOLEAN

13 Reserved BOOLEAN

Modicon  
Standard

Register Number	Absolute Starting Register Address, (Hexa-decimal)	Absolute Starting Register Address, (Decimal)	Bit Data Point Length #	register s	Data Type	Multiply Reading By:	Divide Reading By: Valid Response Scale	14 Reserved BOOLEAN	15 Reserved BOOLEAN	Configuration n	Data
48193	0x2000	8192	RESERVED	3							
48196	0x2003	8195	RESERVED	1							
48198	0x2005	8197	RESERVED								
48199	0x2006	8198	RESERVED								
48200	0x2007	8199	Breaker settings	1 bit = 1, breaker is present							
			0 breaker Q1 (UIB)	BOOLEAN							
			1 breaker Q2 (UOB)	BOOLEAN							
			2 Q3 (MBB)	BOOLEAN							
			3 Q4 (SIB)	BOOLEAN							
			4 Q5 (SSIB)	BOOLEAN							
			5 BB1	BOOLEAN							
			6 BB2	BOOLEAN							
			7 BB3	BOOLEAN							
			8 BB4	BOOLEAN							
			9 BF2	BOOLEAN							
			10 Reserved	BOOLEAN							
			11 Reserved	BOOLEAN							
			12 Reserved	BOOLEAN							

13 Reserved BOOLEAN  
 14 Reserved BOOLEAN  
 15 Reserved BOOLEAN  
 48201 0x2008 8200 Temperature unity 1 ENUM 0 = Celcius  
     1 = Fahrenheit  
 48202 0x2009 8201 UPS environment settings 1  
     0 Input transformer presence BOOLEAN bit = 1, transformer is present  
     1 Output transformer presence BOOLEAN bit = 1, transformer is present  
         2 AC wiring configuration BOOLEAN  
             bit = 0, input cabling 3 wires  
             bit = 1, input cabling 4 wires  
     3 UPS mains supply by single input BOOLEAN bit = 1, mains supply input is single  
     4 UPS mains supply by dual input BOOLEAN bit = 1, mains supply input is dual  
         5 Reserved BOOLEAN  
         6 Reserved BOOLEAN  
         7 Reserved BOOLEAN  
         8 Reserved BOOLEAN  
         9 Reserved BOOLEAN  
         10 Reserved BOOLEAN  
         11 Reserved BOOLEAN  
         12 Reserved BOOLEAN  
         13 Reserved BOOLEAN  
         14 Reserved BOOLEAN  
         15 Reserved BOOLEAN  
 48203 0x200A 8202 SIB breaker label 2 ASCII 4 bytes string = 2 registers, Default value "SIB "  
 48205 0x200C 8204 UIB breaker label 2 ASCII 4 bytes string = 2 registers, Default value UIB "  
     48207 0x200E 8206 SSIB breaker label 2 ASCII 4 bytes string = 2 registers, Default value  
         "SSIB"  
     48209 0x2010 8208 MBB breaker label 2 ASCII 4 bytes string = 2 registers, Default value  
         "MBB "  
     48211 0x2012 8210 UOB breaker label 2 ASCII 4 bytes string = 2 registers, Default value  
         "UOB "  
 48213 0x2014 8212 BF2 breaker label 2 ASCII 4 bytes string = 2 registers, Default value "BF2 "  
     48215 0x2016 8214 BB breaker label 2 ASCII 4 bytes string = 2 registers, Default value "BB "  
         48217 0x2018 8216 UPS Name 9 ASCII 18 bytes string = 8 registers  
     48449 0x2100 8448 Low Battery Alarm Threshold 1 UINT16 1 1 Seconds  
         48450 0x2101 8449 Battery Type 1 ENUM 1 1  
             0=VRLA  
             1=Open Cell  
             2=Lithium-Ion  
             3=NiCd  
             6=NiZn  
     48451 0x2102 8450 Battery Solution 1

ENUM 1 1  
 0=None  
 1=Classic  
 2=NA  
 3=Unknown  
 48452 0x2103 8451 Deep Discharge Allowed  
 1  
 ENUM 1 1  
 0=No  
 1=Yes  
 48453 0x2104 8452 Total Battery Capacity 1 UINT16 1 1 Ah  
 48454 0x2105 8453 Reserved 1 UINT16 1 1  
 48455 0x2106 8454 Number of battery bank for Classical battery 1 UINT16 1 1 Unitless  
 Modicon  
 Standard  
 Register  
 Number  
 Absolute Starting Register Address,  
 (Hexa-decimal)  
 Absolute  
 Starting  
 Register  
 Address,  
 (Decimal)  
 Bit Data Point  
 Length  
 #  
 register  
 s  
 Data Type  
 Multiply  
 Reading  
 By:  
 Divide Reading  
 By: Valid Response  
 Scale  
 48705 0x2200 8704 Nominal Output Voltage 1 ENUM 1 1  
 0=380V  
 1=400V  
 2=415V  
 3=480V  
 4=440V  
 48706 0x2201 8705 Transfer to Static Bypass Disable 1 ENUM 1 1  
 0=Disable

1=Enable  
 48707 0x2202 8706 Reserved 1 ENUM 1 1  
 48708 0x2203 8707 Automatic Battery Disconnect  
 1  
 ENUM 1 1  
 0=No  
 1=Yes  
 48709 0x2204 8708 High Efficiency Mode 1 ENUM 1 1  
 0=Disable  
 1=ECO mode  
 2=ECONversion  
 3=ECONversion Harmonics Compensator  
 48710 0x2205 8709 Reserved 1 1 1  
 48711 0x2206 8710 Number of UPS installed in a parallel installation 1 UINT16  
 48712 0x2207 8711 Number of redundant UPS installed in a parallel installatio 1 UINT16  
 48713 0x2208 8712 Number of redundant Power Cabinet installed in a UPS 1 UINT16  
 48714 0x2209 8713 UPSs presence in parallel installation 1  
 0 UPS 1 presence BOOLEAN  
 bit = 0, UPS 1 not present  
 bit = 1, UPS 1 is present  
 1 UPS 2 presence BOOLEAN  
 bit = 0, UPS 2 not present  
 bit = 1, UPS 2 is present  
 2 UPS 3 presence BOOLEAN  
 bit = 0, UPS 3 not present  
 bit = 1, UPS 3 is present  
 3 UPS 4 presence BOOLEAN  
 bit = 0, UPS 4 not present  
 bit = 1, UPS 4 is present  
 4 UPS 5 presence BOOLEAN  
 bit = 0, UPS 5 not present  
 bit = 1, UPS 5 is present  
 5 Reserved BOOLEAN  
 6 Reserved BOOLEAN  
 7 Reserved BOOLEAN  
 8 Reserved BOOLEAN  
 9 Reserved BOOLEAN  
 10 Reserved BOOLEAN  
 11 Reserved BOOLEAN  
 12 Reserved BOOLEAN  
 13 Reserved BOOLEAN  
 14 Reserved BOOLEAN  
 15 Reserved BOOLEAN  
 48715 0x220A 8714 Frequency Converter Mode 1 ENUM 1 1 0=Disable

1=Enable  
48716 0x220B 8715 Energy Storage Type 1 ENUM 1 1 0=None  
1=Battery  
2=Flywheel48717 0x220C 8716 Number Power Cabinet on the left of IO Cabinet 1 UINT16 1  
1  
48718 0x220D 8717 Continuous Overload Mode Setting 1 UINT16 1 1 %  
Worldwide Customer Support  
Customer support for this or any other product is available at no charge in any of the  
following ways:  
\* Visit the Schneider Electric Web site to access documents in the Schneider Electric  
Knowledge Base and to submit customer support requests.  
– www.schneider-electric.com (Corporate Headquarters)  
Connect to localized Schneider Electric Web sites for specific countries, each of which  
provides customer support information.  
– www.schneider-electric.com/support/  
Global support searching Schneider Electric Knowledge Base and using e-support.  
\* Contact the Schneider Electric Customer Support Center by telephone or e-mail.  
– Local, country-specific centers: go to www.schneider-electric.com > Support > Operations  
around the world for contact information.  
SCHN-01185-V01.01-EN - PEP ECOPASSPORT®- Galaxy VX UPS System  
Product Environmental Profile  
Galaxy VX UPS System  
#Internal  
ENVPEP2311001\_V2 - SCHN-01185-V01.01-EN 2024/4/23  
SCHN-01185-V01.01-EN - PEP ECOPASSPORT®- Galaxy VX UPS System  
3600 kg  
Plastics  
Metals  
Others 22.70%  
General information  
Reference product Galaxy VX 1250kVA, 400V, Start up 5x8 - GVX1250K1250NHS  
Constituent materials  
This document provides environmental impact and performance of the product based on  
Life Cycle Assessment (LCA), from cradle to grave (materials, manufacturing,  
distribution, installation, use and end of life).  
Reference product mass including the product, its packaging and additional elements and  
accessories  
4.80%  
72.50%  
Description of the product The Galaxy VX is a scalable, highly efficient 500 - 1500KVA 3  
phase Uninterruptible Power Supply (UPS) system that provides  
seamless power protection for large sized data centers, industrial and facilities applications.  
Description of the range  
Galaxy VX UPS System

The representative product is 1250 kW rating (5 Power Cabinets) with 1250 kW I/O Cabinet (GVX1250K1250NHS).

The environmental impacts of this referenced product are representative of the impacts of the other products of the range which are developed with a similar technology. Meanwhile, environmental details of other kVA ratings are available in supplementary information at the end of this document.

Functional unit To protect the load of 1250 kW against input power failure during 15 years and switch to the energy storage system to avoid power outage.

Steel - 42%

Copper - 16.6%

Aluminium - 12.8%

Tin - 0.5%

Ferrous alloys - 0.3%

Brass - 0.3%

Electronic components -  
16.6%

Wood - 3.6%

Cardboard - 1.3%

Miscellaneous - 0.4%

Various - 0.8%

PC Polycarbonate - 2.6% UP Polyester - 0.5%

PE Polyethylene - 0.5%

PA Polyamide - 0.4%

Diverse Thermosetting

Plastics - 0.4%

ABS Acrylonitrile Butadiene

Styrene - 0.4%

#Internal

ENVPEP2311001\_V2 - SCHN-01185-V01.01-EN 2024/4/23

SCHN-01185-V01.01-EN - PEP ECOPASSPORT®- Galaxy VX UPS System

RoHS compliance

REACH compliance

Battery Directive  
compliance

End Of Life 76%

Use scenario

Power consumption conforms to the requirements in PSR0010-ed1.1-EN-2015\_10\_16\_UPS:

The referent UPS can operate in 2 modes. It has an average energy efficiency of 95.8% in Double Conversion mode and 98.6% in

eConversion mode. Total energy losses are calculated to be 3418454 kWh in Double Conversion and 1047094 kWh in eConversion after 15

years.

Geographical representativeness Europe	
Energy model used	
[A1 - A3] [A5] [B6] [C1 - C4]	
Electricity Mix; Production mix; Low voltage; IN Electricity Mix; Production mix; Low voltage; UE-27	
Electricity Mix; Production mix; Low voltage; UE-27	
Electricity Mix; Production mix; Low voltage; UE-27	
Technological representativeness	
The Modules of Technologies such as material production, manufacturing process and transport technology used in this PEP analysis (LCA- EIME in this case) are Similar and representative of the actual type of technologies used to make the product in production.	
Environmental impacts	
Reference service life time 15 years	
Installation elements The disposal of the packaging materials is accounted for 6% during the installation phase (including transport to disposal).	
Substance assessment	
Details of ROHS and REACH substances information are available on the Schneider-Electric Green Premium website	
<a href="https://www.se.com/ww/en/work/support/green-premium/">https://www.se.com/ww/en/work/support/green-premium/</a>	
Additional environmental information	
Recyclability potential:	
Recyclability rate has been calculated based on REEECY'LAB tool developed by Ecosystem, for components/materials not covered by the tool, data from the "ECO'DEEE recyclability and recoverability calculation method" was taken. If no data was found a conservative assumption was used (0% recyclability).	
Products of this range are designed in conformity with the requirements of the RoHS directive (European Directive 2011/65/EU of 8 June 2011) on restriction of lead, mercury, cadmium, hexavalent chromium or flame retardants - PBB&PBDE or phthalates-DEHP, BBP, DBP, DIBP.	
Products of this range are designed in conformity with the requirements of the REACH 1907/2006 regulation and its latest updates.	
The battery within this product range are designed in conformity with the requirements of the Battery and Accumulator Directive (European Directive 2006/66/EC of 26 September 2006).Average energy efficiency Electricity consumption (kWh)	

over 15 years)									
Average energy									
efficiency									
Electricity									
consumption (kWh									
over 15 years)									
500 kW with 1250 kW I/O Cabinet	95.6%	1.45E+06	98.6%	4.52E+05					
625 kW with 1250 kW I/O Cabinet	95.6%	1.81E+06	98.2%	6.78E+05					
750 kW with 1250 kW I/O Cabinet	95.6%	2.17E+06	98.4%	7.51E+05					
800 kW with 1250 kW I/O Cabinet	95.7%	2.23E+06	98.3%	8.02E+05					
1000 kW with 1250 kW I/O Cabinet	95.8%	2.76E+06	98.6%	8.71E+05					
1100 kW with 1250 kW I/O Cabinet	95.9%	2.98E+06	98.6%	9.58E+05					
1250 kW with 1250 kW I/O Cabinet	95.8%	3.42E+06	98.6%	1.05E+06					
500 kW with 1500 kW I/O Cabinet	96.4%	1.19E+06	99.0%	3.20E+05					
750 kW with 1500 kW I/O Cabinet	96.2%	1.90E+06	98.9%	5.05E+05					
1000 kW with 1500 kW I/O Cabinet	96.0%	2.65E+06	98.9%	6.73E+05					
1250 kW with 1500 kW I/O Cabinet	96.2%	3.20E+06	99.0%	7.60E+05					
1500 kW with 1500 kW I/O Cabinet	96.2%	3.84E+06	99.0%	9.12E+05					
Type (400V UPS system)									
Double conversion eConversionAverage energy									
efficiency									
Electricity									
consumption (kWh									
over 15 years)									
Average energy									
efficiency									
Electricity									
consumption (kWh									
over 15 years)									
500 kW with 1250 kW I/O Cabinet	95.7%	1.38E+06	98.0%	5.83E+05					
625 kW with 1250 kW I/O Cabinet	95.9%	1.61E+06	98.2%	6.78E+05					
750 kW with 1250 kW I/O Cabinet	95.9%	1.98E+06	98.4%	7.51E+05					
800 kW with 1250 kW I/O Cabinet	95.9%	2.08E+06	98.3%	8.02E+05					
1000 kW with 1250 kW I/O Cabinet	96.1%	2.51E+06	98.6%	8.46E+05					
1100 kW with 1250 kW I/O Cabinet	96.2%	2.68E+06	98.5%	9.67E+05					
1250 kW with 1250 kW I/O Cabinet	96.2%	3.08E+06	98.6%	1.06E+06					
500 kW with 1500 kW I/O Cabinet	96.2%	1.23E+06	98.9%	3.20E+05					
750 kW with 1500 kW I/O Cabinet	96.3%	1.80E+06	98.9%	5.05E+05					
1000 kW with 1500 kW I/O Cabinet	96.3%	2.37E+06	98.9%	6.73E+05					
1250 kW with 1500 kW I/O Cabinet	96.4%	2.92E+06	99.0%	7.60E+05					
1500 kW with 1500 kW I/O Cabinet	96.3%	3.58E+06	99.0%	9.12E+05					
Type (480V UPS system)									
Double conversion eConversionLoad rate 25% 50% 75% 100%									
Proportion of time at specified load 0.25 0.5 0.25 0									

#Internal  
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SCHN-01185-V01.01-EN - PEP ECOPASSPORT®- Galaxy VX UPS System  
Detailed results, including all the optional indicators mentioned in PCRed4, and the split of  
the Use Phase (B1 to B7), are available in the LCA report  
and on demand in a digital format - Country Customer Care Center - <http://www.schneider-electric.com/contact>  
kg CO2 eq  
kg CO2 eq  
kg CO2 eq  
kg CO2 eq  
kg CFC-11  
eq  
mol H+ eq  
kg  
(PO4)<sup>3-</sup>eq  
kg N eq  
mol N eq  
kg COVNM  
eq  
kg Sb eq  
MJ  
m3 eq  
Additional indicators for the French regulation are available as well  
MJ  
MJ  
MJ  
MJ  
MJ  
MJ  
MJ  
kg  
MJ  
MJ  
m<sup>3</sup>  
Contribution to use of non renewable secondary fuels  
Contribution to net use of freshwater  
0.00E+00  
2.56E+03 3.77E+02 1.23E+00 1.76E+00 1.15E+03 1.03E+03 -6.12E+03  
0.00E+00 0\* 0\* 0\* 0\* 0\*  
Contribution to total use of renewable primary energy resources 6.88E+06 2.29E+04 0\* 0\*  
6.85E+06  
0\* -9.45E+03  
3.68E+07 7.30E+05 1.26E+04 0\* 3.57E+07 3.52E+05 -8.62E+06  
0.00E+00

0.00E+00 0* 0* 0* 0* 0* 0.00E+00	
1.27E+00 1.27E+00 0* 0* 0* 0* Contribution to use of secondary material	
Contribution to total use of non-renewable primary energy resources	
Contribution to use of renewable secondary fuels	
3.17E+03 -1.91E+05	
Contribution to use of renewable primary energy resources used as raw material	
3.89E+03 3.89E+03 0* 0* 0* 0* -7.67E+03	
Contribution to use of renewable primary energy excluding renewable primary energy used as raw material	
6.88E+06 1.90E+04 0* 0* 6.85E+06	
Contribution to use of non renewable primary energy resources used as raw material	
1.19E+04 1.19E+04 0* 0* 0*	
3.17E+03 -1.99E+05	
Contribution to use of non renewable primary energy excluding non renewable primary energy used as raw material	
3.68E+07 7.18E+05 1.26E+04 0*	
3.57E+07 3.52E+05 -8.61E+06	
Inventory flows Indicators Galaxy VX UPS System - G VX1250K1250NHS	
Inventory flows Unit Total	
Manufact. Distribution Installation	
Contribution to water use	
1.06E+05 1.62E+04 5.26E+01 7.58E+01 4.96E+04	
Use End of Life Benefits	
[A1 - A3] [A4] [A5] [B1 - B7] [C1 - C4] [D]	
1.26E-01 -1.07E+02	
Contribution to resource use, fossils	
3.68E+07 7.30E+05 1.26E+04 0* 3.57E+07 3.52E+05 -8.62E+06	
Contribution to resource use, minerals and metals	
7.93E+00 7.70E+00 0* 0* 1.02E-01 3.99E+04 -2.63E+05	
Contribution to eutrophication marine	
1.01E+03 9.22E+01 2.07E+00 1.66E-01 9.08E+02 7.38E+00 -2.70E+02	
Contribution to eutrophication, freshwater	
8.49E+00 1.77E-01 0* 2.19E-03 3.84E+00 6.43E+01 -3.10E+03	
Contribution to photochemical ozone formation - human health	
3.26E+03 3.15E+02 7.36E+00 4.29E-01 2.92E+03 1.94E+01 -1.20E+03	
Contribution to eutrophication, terrestrial	
1.49E+04 1.18E+03 2.25E+01 0* 1.36E+04 1.08E-04 -7.02E-02	
Contribution to acidification	
8.89E+03 8.50E+02 4.51E+00 0* 8.00E+03 3.55E+01 -5.07E+03	
Contribution to ozone depletion	
1.99E-02 1.29E-02 9.16E-04 8.90E-06 5.99E-03 4.48E+00 -9.84E-01	
Contribution to climate change-fossil	
1.50E+06 9.24E+04 1.04E+03 2.89E+02 1.40E+06 6.12E+03 -4.38E+05	
Contribution to climate change	
1.50E+06 9.31E+04 1.04E+03 2.18E+02 1.40E+06 1.31E+02 -7.38E+03	
Contribution to climate change-land use and land use change	
2.27E-03 5.00E-05 0* 1.20E-04 0* 2.10E-03 0.00E+00	

Contribution to climate change-biogenic 2.60E+03 6.69E+02 0\* 0\* 1.87E+03

Impact indicators Unit Total

Manufacturing Distribution Installation Use End of Life Benefits

[A1 - A3] [A4] [A5] [B1 - B7] [C1 - C4] [D]

6.25E+03 -4.46E+05

Mandatory Indicators Galaxy VX UPS System - GVX1250K1250NHS

\*Net benefits and loads beyond the system boundaries stage (module D): potential for reuse, recovery and/or recycling, expressed as net benefits and impacts.

#Internal

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SCHN-01185-V01.01-EN - PEP ECOPASSPORT®- Galaxy VX UPS System

kg

kg

kg

kg

kg

kg

MJ

kg de C

kg de C

Referent

product

500 625 750 800 1000 1100 1250 500 750 1000 1250 1500

1 1 1 1 1 1 1 1 1 1 1 1

2 3 3 4 4 5 5 2 3 4 5 6

1920 2480 2480 3040 3040 3600 3600 2180 2740 3300 3860 4420

6.37E+05 8.00E+05 9.48E+05 9.86E+05 1.20E+06 1.31E+06 1.50E+06 5.42E+05 8.46E+05

1.17E+06 1.41E+06 1.68E+06

8.86E-03 1.15E-02 1.21E-02 1.42E-02 1.52E-02 1.76E-02 1.99E-02 9.37E-03 1.26E-02 1.59E-02 1.89E-02 2.21E-02

3.79E+03 4.76E+03 5.61E+03 5.87E+03 7.12E+03 7.76E+03 8.89E+03 3.26E+03 5.05E+03

6.93E+03 8.34E+03 9.97E+03

3.74E+00 4.82E+00 5.23E+00 5.96E+00 6.56E+00 7.48E+00 8.49E+00 3.78E+00 5.25E+00

6.76E+00 8.05E+00 9.44E+00

4.30E+02 5.41E+02 6.37E+02 6.68E+02 8.09E+02 8.83E+02 1.01E+03 3.71E+02 5.74E+02

7.88E+02 9.49E+02 1.13E+03

6.35E+03 7.98E+03 9.42E+03 9.84E+03 1.20E+04 1.30E+04 1.49E+04 5.44E+03 8.45E+03

1.16E+04 1.40E+04 1.67E+04

1.39E+03 1.75E+03 2.05E+03 2.15E+03 2.61E+03 2.85E+03 3.26E+03 1.20E+03 1.85E+03

2.54E+03 3.06E+03 3.66E+03

3.61E+00 4.75E+00 4.76E+00 5.90E+00 5.91E+00 7.05E+00 7.93E+00 4.14E+00 5.29E+00

6.44E+00 7.59E+00 8.74E+00

1.85E+07 2.32E+07 2.77E+07 2.86E+07 3.52E+07 3.81E+07 3.68E+07 1.55E+07 2.44E+07

3.39E+07 4.09E+07 4.91E+07

4.66E+04 6.00E+04 6.52E+04 7.42E+04 8.19E+04 9.33E+04 1.06E+05 4.68E+04 6.52E+04  
 8.42E+04 1.00E+05 1.18E+05  
 2.29E+05 3.36E+05 3.66E+05 4.01E+05 4.29E+05 4.79E+05 5.26E+05 1.83E+05 2.72E+05  
 3.55E+05 4.04E+05 4.80E+05  
 500 625 750 800 1000 1100 1250 500 750 1000 1250 1500  
 1 1 1 1 1 1 1 1 1 1 1 1  
 2 3 3 4 4 5 5 2 3 4 5 6  
 1920 2480 2480 3040 3040 3600 3600 2180 2740 3300 3860 4420  
 6.09E+05 7.18E+05 8.72E+05 9.27E+05 1.10E+06 1.19E+06 1.35E+06 5.57E+05 8.03E+05  
 1.05E+06 1.29E+06 1.58E+06  
 8.74E-03 1.12E-02 1.18E-02 1.40E-02 1.47E-02 1.71E-02 1.78E-02 9.44E-03 1.24E-02 1.55E-  
 02 1.84E-02 2.16E-02  
 3.62E+03 4.29E+03 5.17E+03 5.53E+03 6.54E+03 7.07E+03 7.99E+03 3.35E+03 4.80E+03  
 6.28E+03 7.67E+03 9.37E+03  
 3.66E+00 4.60E+00 5.02E+00 5.80E+00 6.29E+00 7.15E+00 7.59E+00 3.82E+00 5.13E+00  
 6.45E+00 7.73E+00 9.15E+00  
 4.12E+02 4.88E+02 5.88E+02 6.29E+02 7.44E+02 8.03E+02 9.09E+02 3.81E+02 5.46E+02  
 7.13E+02 8.72E+02 1.06E+03  
 6.07E+03 7.18E+03 8.68E+03 9.26E+03 1.10E+04 1.18E+04 1.34E+04 5.58E+03 8.03E+03  
 1.05E+04 1.29E+04 1.57E+04  
 1.33E+03 1.58E+03 1.90E+03 2.03E+03 2.40E+03 2.59E+03 2.93E+03 1.23E+03 1.76E+03  
 2.30E+03 2.81E+03 3.43E+03  
 Contribution to hazardous waste disposed  
 Contribution to radioactive waste disposed  
 Contribution to non hazardous waste disposed  
 0\* 0.00E+00  
 \* represents less than 0.01% of the total life cycle of the reference flow  
 Life cycle assessment performed with EIME version v5.9.4, database version 2022-01 in  
 compliance with ISO14044.  
 Detailed results, including all the optional indicators mentioned in PCRed4, and the split of  
 the Use Phase (B1 to B7), are available in the LCA report  
 and on demand in a digital format - Country Customer Care Center - <http://www.schneider-electric.com/contact>  
 \*\* Net benefits and loads beyond the system boundaries stage (module D): potential for  
 reuse, recovery and/or recycling, expressed as net benefits and impacts. Not  
 accounted in the Total.  
 Environmental indicators- 'Total' of  
 Life  
 Cycle Phases  
 (UPS in eConversion mode)  
 Contribution to climate change (kg CO2 eq)  
 480V UPS system Galaxy VX UPS (kVA) with 1250 kW I/O Cabinet Galaxy VX UPS (kVA) with  
 1500 kW I/O  
 Cabinet



(kgSbeq)  
Total use of primary energy (MJ)  
Contribution to water use (m3 eq)  
Compulsory environmental  
indicators - 'Total' of Life  
Cycle Phases  
(UPS in Double conversion mode)  
Contribution to climate change (kg CO2 eq)  
Contribution to Ozone depletion (kg CFC11 eq)  
Contribution to Acidification (mol H+ eq)  
Contribution to eutrophication, freshwater (kg PO43-  
eq)  
Contribution to eutrophication marine (kg N eq)  
Contribution to eutrophication, terrestrial (mol N eq)  
Contribution to photochemical ozone formation -  
human health (kg COVNM eq)  
#Internal  
ENVPEP2311001\_V2 - SCHN-01185-V01.01-EN 2024/4/23  
SCHN-01185-V01.01-EN - PEP ECOPASSPORT®- Galaxy VX UPS System  
3.61E+00 4.74E+00 4.76E+00 5.89E+00 5.90E+00 7.04E+00 7.05E+00 4.14E+00 5.29E+00  
6.44E+00 7.58E+00 8.74E+00  
1.76E+07 2.07E+07 2.54E+07 2.68E+07 3.21E+07 3.44E+07 3.93E+07 1.59E+07 2.31E+07  
3.05E+07 3.74E+07 4.59E+07  
4.56E+04 5.71E+04 6.25E+04 7.21E+04 7.83E+04 8.90E+04 9.47E+04 4.73E+04 6.37E+04  
8.02E+04 9.62E+04 1.14E+05  
2.83E+05 3.36E+05 3.66E+05 4.01E+05 4.19E+05 4.83E+05 5.20E+05 1.83E+05 2.72E+05  
3.55E+05 4.05E+05 4.81E+05  
Internal External  
5 years  
2024/4/23  
CS 30323  
F- 92500 Rueil Malmaison Cedex  
RCS Nanterre 954 503 439  
Capital social 896 313 776 €  
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Country Customer Care Center  
http://www.schneider-electric.com/contact  
35, rue Joseph Monier  
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Independent verification of the declaration and data, in compliance with ISO 14025 : 2010  
X  
The PCR review was conducted by a panel of experts chaired by Julie ORGELET (DDemain)  
PEP are compliant with XP C08-100-1 :2016 or EN 50693:2019

<p>The elements of the present PEP cannot be compared with elements from another program.</p> <p>Document in compliance with ISO 14025 : 2010 « Environmental labels and declarations. Type III environmental declarations »</p> <p>Date of issue 2024/4/23 Information and reference documents</p> <p>Registration number : SCHN-01185-V01.01-EN Drafting rules PEP-PCR-ed4-2021 09 06</p> <p>Verifier accreditation N° VH08 Supplemented by <a href="http://www.pep-ecopassport.org">www.pep-ecopassport.org</a></p> <p>Validity period PSR-0010-ed1.1-2015 10 16</p> <p>Environmental indicators- 'Total' of Life Cycle Phases (UPS in eConversion mode)</p> <p>Contribution to climate change (kg CO2 eq)</p> <p>Other Additional information</p> <p>Operating the Galaxy VX in eConversion mode results in significantly reduced environmental impact, in particular Carbon emissions (up to 65% reduction) compared to operation in Double Conversion mode. This is mainly due to an improved energy efficiency in eConversion of 98.6% (average) compared to an efficiency of 95.8% (average) in Double Conversion mode.</p> <p>For details about eConversion, consult the Schneider-Electric eConversion page: <a href="https://www.se.com/ww/en/work/products/product-launch/econversion-high-efficiency-UPS-mode/">https://www.se.com/ww/en/work/products/product-launch/econversion-high-efficiency-UPS-mode/</a></p> <p>Compulsory environmental indicators - 'Total' of Life Cycle Phases (UPS in Double conversion mode)</p> <p>Contribution to resource use, minerals and metals (kgSbeq)</p> <p>Total use of primary energy (MJ)</p> <p>Contribution to water use (m3 eq)</p> <p>#Internal</p> <p>ENVPEP2311001_V2 - SCHN-01185-V01.01-EN 2024/4/23</p>		

